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A comparison of the "Defibrination" and "Oxalate" methods of Seru Preparation as applied to Haemorrhagic Septicaemia and Anthrax Sera together with some Analyses of Buffalo aud Hill Bull Blood

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A comparison of the "Defibrination" and "Oxalate" methods of Serum Preparation as applied to Haemorrhagic Septicaemia and Anthrax Sera together with some Analyses of Buffalo and Hill Bull Blood.

Introduction.

IN the following notes a brief account is given of some comparative experiments carried out on the preparation of Hæmorrhagic Septicæmia and Anthrax sera by two different methods, the chief object in view being to study the influence of the method on the yield and quantity of the serum. As regards yield this depends on several factors, *e.g.*, (1) the nature of the animal and (2) nature of the bleeding. The animals used in this laboratory are chiefly buffaloes and hill bulls. Formerly, each animal after immunisation was bled twice with an interval of two days between the bleedings, the first bleeding being at the rate of 6 cc. per lb. body weight and the second at 8 cc. This method, however, is now discontinued and three bleedings are taken in each series, all three being at the rate of 6 cc. per lb. body weight and with an interval of 4 days between each bleeding. It is found that more serum can be obtained from the second bleeding than from the first while the third gives the largest percentage of all. Hence in the tables which follow the bleedings have been classified into three groups according as they were the 1st, 2nd and 3rd in a series.

Defibrination method.

The blood is drawn into bottles containing a coil of copper wire, defibrinated by shaking and the defibrinated blood then centrifugalised. advantages of the method are (1) great simplicity and (2) rapidity. On the other hand, the serum is usually of a bad colour containing an appreciable amount of hæmoglobin. When carbolised a considerable deposit settles out and on standing the colour becomes extremely dark.

Oxalate method.

The blood is drawn into bottles containing a small quantity of potassium oxalate solution, the latter being used at the rate of 10 cc. of a 10 per cent. solution to each litre of blood. The bottle is rotated to secure thorough mixing and the blood is then allowed to stand. In the case of *buffaloes*, in a few hours, the corpuscles have almost completely settled and a large proportion (50 per cent. of the blood) of the clear plasma can be syphoned off. The residue in the bottle is then centrifugalised when another 10-15 per cent. plasma is obtained.

In the case of *hill bulls*, the corpuscles settle with extreme difficulty and it is usually necessary to centrifugalise the whole of the blood. This curious difference which is of course of great practical importance will be dealt with again later in this paper. The oxalated plasma obtained in the above manner is then clotted by the addition of 10 cc. of a 12 per cent. solution of calcium chloride to each litre of plasma. An extremely tough, almost white clot forms in a few minutes. This, on separation from the sides of the vessel, rapidly contracts to a very small bulk, this process being accelerated by the addition of weights. The majority of the corpuscles having been removed before the clot forms, the expressed serum is of an extremely good appearance, being free from any red colouration, a point of some importance in this country. When carbolised, moreover, serum prepared in this way exhibits much less precipitation than that obtained by defibrination and in the limited time of observation possible, since this method was begun, does not appear to darken in colour so readily. Finally, it has been found that the yields of serum obtained by the oxalate method are, as a rule, markedly higher than by defibrination. This last factor in itself amply repays the increased time required for the oxalate method.

In the following tables are given the results obtained with hæmorrhagic septicæmia and anthrax sera by the two methods. As the tables are classified according to the nature of the bleeding the influence of this factor can also be observed.

TABLE I.

HÆMORRHAGIC SEPTICÆMIA. DEFIBRINATION METHOD.

Buffaloes. *1st Bleedings.*

Series	Volume of blood taken cc.	Volume of defibrinated blood obtained	Percentage yield of defibrinated blood	Serum		
				Volume obtained	Percentage of defibrinated blood	Percentage of whole blood drawn
1	3,800	2,850	75·0	1,900	66·7	**50·0**
2	15,800	13,150	83·4	7,300	55·5	**46·2**
3	3,000	2,450	81·7	1,250	51·0	**41·7**
4	5,900	4,250	72·2	2,900	68·2	**49·6**
5	4,700	3,250	69·1	2,350	72·3	**50·0**
6	5,700	4,900	85·9	3,100	63·3	**54·4**
7	3,400	2,800	82·3	2,000	71·4	**58·8**
8	9,300	7,800	83·9	5,050	64·7	**54·3**
TOTAL	51,600	41,450	80·3	25,850	62·4	**50·1**

Average yields—
- (1) Defibrinated blood . . . . 80·0
- (2) Serum—
  - (*a*) Percentage of defibrinated blood . . . . 64·1
  - (*b*) Percentage of blood drawn . . . . . **50·6**

TABLE II.

HÆMORRHAGIC SEPTICÆMIA. OXALATE METHOD.

Buffaloes. *1st Bleedings.*

Series	Volume of blood taken cc.	Volume of plasma obtained	Percentage yield of plasma	Serum		
				Volume obtained	Percentage of plasma	Percentage of whole blood drawn
1	1,300	1,000	76·9	900	90·0	**69·2**
2	1,500	1,050	70·0	950	90·5	**63·3**
3	10,200	6,400	62·7	5,030	78·6	**49·3**
4	2,900	1,700	58·6	1,400	82·4	**48·2**
5	3,400	2,300	67·6	2,100	91·3	**61·1**
6	3,200	1,800	56·2	1,550	91·6	**48·5**
7	1,800	1,100	61·1	1,000	90·9	**55·5**
TOTAL .	24,300	15,350	63·5	12,930	84·2	**53·4**

Average yields—
(1) Plasma . . . . 64·7
(2) Serum—
(*a*) Percentage of plasma . . . 87·9
(*b*) Percentage of whole blood drawn . **56·4**

TABLE III.

HÆMORRHAGIC SEPTICÆMIA. DEFIBRINATION METHOD.

Buffaloes. *2nd Bleedings.*

Series	Volume of blood taken cc.	Volume of defibrinated blood obtained	Percentage yield of defibrinated blood	Serum		
				Volume obtained	Percentage of defibrinated blood	Percentage of whole blood drawn
1	9,900	8,200	82·8	5,170	63·0	**52·2**
2	5,000	3,850	77·0	2,400	62·3	**48·0**
3	13,700	11,200	81·7	6,950	62·0	**50·7**
4	1,300	1,050	80·8	700	66·7	**53·9**
5	3,000	2,250	75·0	1,450	64·5	**48·3**
6	5,600	4,900	87·5	3,300	67·4	**58·9**
TOTAL	38,500	31,450	81·7	19,970	63·5	**51·9**

Average yields—
(1) Defibrinated blood . . . . 81·0
(2) Serum—
(*a*) Percentage of defibrinated blood . . . . 64·2
(*b*) Percentage of whole blood drawn . . . **52·0**

TABLE IV.

HÆMORRHAGIC SEPTICÆMIA. OXALATE METHOD.

Buffaloes. *2nd Bleedings.*

Series	Volume of blood taken cc.	Volume of plasma obtained	Percentage yield of plasma	Serum		
				Volume obtained	Percentage of plasma	Percentage of whole blood drawn
1	1,500	900	60·0	830	92·2	**55·3**
2	6,300	4,200	66·7	3,950	94·0	**62·7**
3	7,300	5,350	73·3	5,100	95·3	**69·9**
4	1,600	1,100	68·7	1,000	90·9	**62·5**
5	8,300	4,500	54·3	4,200	93·3	**50·6**
6	2,900	1,850	63·8	1,650	89·2	**56·8**
7	2,900	1,800	62·2	1,650	91·6	**56·8**
TOTAL .	30,800	19,700	63·9	18,380	93·4	**59·6**

Average yields—

(1) Plasma . . . . 64·1

(2) Serum—

(a) Percentage of plasma . . . . . . 92·3

(b) Percentage of whole blood drawn . . . **59·2**

TABLE V.

HÆMORRHAGIC SEPTICÆMIA. DEFIBRINATION METHOD.

Buffaloes. *3rd Bleedings.*

Series	Volume of blood taken cc.	Volume of defibrinated blood obtained	Percentage yield of defibrinated blood	Serum		
				Volume obtained	Percentage of defibrinated blood	Percentage of whole blood drawn
1	5,600	4,350	77·7	3,200	73·6	**57·2**
2	2,200	1,900	83·7	1,200	63·2	**54·5**
3	11,000	9,550	86·8	6,400	67·0	**58·2**
4	1,300	1,050	80·8	750	71·4	**57·7**
5	3,000	2,550	85·0	1,950	76·5	**65·0**
TOTAL .	23,100	19,400	84·0	13,500	69·6	**58·4**

Average yields—

(1) Defibrinated blood . . . . 82·8

(2) Serum—

(a) Percentage of defibrinated blood . . . . 70·3

(b) Percentage of whole blood drawn . . . **58·5**

TABLE VI.

HÆMORRHAGIC SEPTICÆMIA. OXALATE METHOD.

Buffaloes. *3rd Bleedings.*

Series	Volume of blood drawn cc.	Volume of plasma obtained	Percentage yield of plasma	Serum		
				Volume obtained.	Percentage of plasma	Percentage of whole blood
1	10,600	6,150	58·0	6,100	99·0	**57·5**
2	1,700	1,000	58·8	970	97·0	**57·1**
3	2,700	2,100	77·8	1,900	90·5	**70·4**
4	7,600	5,200	68·4	4,750	91·4	**62·5**
5	1,300	900	69·2	850	94·4	**65·4**
6	3,300	2,300	70·0	2,050	89·1	**62·1**
7	3,400	2,600	76·4	2,350	90·4	**68·8**
8	8,300	5,250	63·2	4,800	91·4	**57·8**
9	3,200	2,300	71·9	2,050	89·1	**64·0**
TOTAL	42,100	27,800	66·2	25,820	92·8	**61·5**

Average yields—
- (1) Plasma . . . . 68·2
- (2) Serum—
  - (*a*) Percentage of plasma . . . . . . 92·5
  - (*b*) Percentage of whole blood drawn . . . . **62·8**

TABLE VII.

HÆMORRHAGIC SEPTICÆMIA. DEFIBRINATION METHOD.

Hill Bulls. *1st Bleedings.*

Series	Volume of blood taken cc.	Volume of defibrinated blood obtained	Percentage yield of defibrinated blood	Serum		
				Volume obtained	Percentage of defibrinated blood	Percentage of whole blood drawn
1	1,900	1,700	89·5	1,000	58·8	**52·6**
2	15,900	12,900	81·1	5,600	43·4	**35·2**
3	1,900	1,500	78·9	950	63·3	**50·0**
4	10,500	8,550	81·4	5,800	67·8	**55·2**
TOTAL	30,200	24,650	81·6	13,350	54·1	**44·2**

Average yields—
- (1) Defibrinated blood . . . . 82·7
- (2) Serum—
  - (*a*) Percentage of defibrinated blood . . . 58·4
  - (*b*) Percentage of whole blood drawn . . . **48·2**

TABLE VIII.

HÆMORRHAGIC SEPTICÆMIA. OXALATE METHOD.

Hill Bulls. *1st Bleedings.*

Series	Volume of blood taken cc.	Volume of plasma obtained	Percentage yield of plasma	Serum		
				Volume obtained	Percentage of plasma	Percentage of whole blood drawn
1	12,100	7,350	60·7	6,800	92·5	**56·2**
2	2,000	1,380	69·0	1,250	90·6	**62·5**
3	2,000	1,250	62·5	1,050	84·0	**52·5**
TOTAL	16,100	9,980	62·0	9,100	91·2	**56·5**

Average yields—
(1) Plasma . . . . 64·1
(2) Serum—
(*a*) Percentage of plasma . . . . 89·0
(*b*) Percentage of whole blood drawn . . . **57·1**

TABLE IX.

HÆMORRHAGIC SEPTICÆMIA. DEFIBRINATION METHOD.

Hill Bulls. *2nd Bleedings.*

Series	Volume of blood taken cc.	Volume of defibrinated blood obtained	Percentage yield of defibrinated blood	Serum		
				Volume obtained	Percentage of defibrinated blood	Percentage of whole blood drawn
1	16,100	11,700	72·7	8,500	72·6	**52·7**

TABLE X.

HÆMORRHAGIC SEPTICÆMIA. OXALATE METHOD.

Hill Bulls. *2nd Bleedings.*

Series	Volume of blood taken cc.	Volume of plasma obtained	Percentage yield of plasma	Serum		
				Volume obtained	Percentage of plasma	Percentage of whole blood drawn
1	12,100	7,150	59·1	6,550	91·6	**54·1**
2	14,100	8,050	57·1	7,250	90·0	**51·4**
3	2,000	1,350	67·5	1,250	92·6	**62·5**
4	3,600	2,300	63·9	2,050	89·2	**57·2**
TOTAL .	31,800	18,850	61·9	17,100	90·8	**53·7**

Average yields—
(1) Plasma . . . . 59·4
(2) Serum—
(*a*) Percentage of plasma . . . . . 90·8
(*b*) Percentage of whole blood taken . . . **56·2**

TABLE XI.

HÆMORRHAGIC SEPTICÆMIA. OXALATE METHOD.

Hill Bulls. *3rd Bleedings.*

Series	Volume of blood taken cc.	Volume of plasma obtained	Percentage yield of plasma	Serum		
				Volume obtained.	Percentage of plasma	Percentage of whole blood drawn
1	12,100	7,550	62·4	6,150	81·5	**50·8**
2	2,000	1,300	65·0	1,200	92·3	**60·0**
3	1,500	900	60·0	800	88·8	**53·3**
4	14,100	9,750	69·1	8,750	89·2	**61·7**
TOTAL .	29,700	19,500	65·6	16,850	86·4	**56·7**

Average yields—
(1) Plasma . . . . 64·1
(2) Serum—
(*a*) Percentage of plasma . . . . . 88·0
(*b*) Percentage of whole blood drawn . . . **56·4**

For the sake of ready comparison the results obtained with hæmorrhagic septicæmia serum are summarized in Table XII below: —

TABLE XII.

HÆMORRHAGIC SEPTICÆMIA. SERUM YIELDS.

Animal	Nature of bleeding	Average yield of serum. Percentage of whole blood drawn — Defibrination method	Oxalate method
	Bleedings.		
Buffaloes	1st	50·6	56·4
"	2nd	52·0	59·2
"	3rd	58·5	62·8
Hill Bulls	1st	48·3	57·1
" "	2nd	52·7	56·2
" "	3rd	..	56·4

TABLE XIII.

ANTHRAX. DEFIBRINATION METHOD.

Buffaloes. *1st Bleedings.*

Series	Volume of blood taken cc.	Volume of defibrinated blood obtained	Percentage yield of defibrinated blood	Serum — Volume obtained	Serum — Percentage of defibrinated blood	Serum — Percentage of whole blood drawn
1	1,900	1,600	84·2	900	56·2	47·4
2	12,100	10,400	85·9	5,900	56·7	48·6
3	2,200	1,850	84·1	1,400	75·7	63·6
4	11,100	9,350	84·2	3,650	39·0	32·9
5	23,900	19,650	82·2	10,250	52·2	42·9
6	1,500	1,400	93·3	800	57·2	53·3
7	1,900	1,600	84·2	1,000	62·5	52·6
8	15,000	12,800	85·3	6,800	53·1	45·3
TOTAL	69,600	58,650	84·3	30,700	52·3	44·1

Average yields—
(1) Defibrinated blood . . . . . . 85·4
(2) Serum—
(a) Percentage of defibrinated blood . . . 56·6
(b) Percentage of whole blood drawn . . . 48·6

TABLE XIV.

ANTHRAX. OXALATE METHOD.

Buffaloes. *1st Bleedings.*

Series	Volume of blood taken cc.	Volume of plasma obtained	Percentage yield of plasma	Serum		
				Volume obtained	Percentage of plasma	Percentage of whole blood drawn
1	6,500	3,950	60·8	3,620	91·6	**55·7**
2	3,200	1,730	53·0	1,520	87·9	**47·5**
3	19,000	11,350	59·7	10,250	90·3	**53·9**
4	5,100	2,900	56·9	2,700	93·1	**52·9**
5	5,100	3,500	68·6	3,250	92·9	**63·7**
6	3,400	2,500	73·5	2,300	92·0	**67·6**
7	7,400	4,450	60·1	3,900	87·6	**54·0**
8	13,700	9,200	67·1	8,100	88·0	**59·0**
9	14,500	9,500	65·5	8,050	84·7	**55·5**
10	13,600	8,700	64·0	7,750	89·1	**56·2**
TOTAL .	91,500	57,780	63·1	51,440	89·0	**56·2**

Average yields—
(1) Plasma . . . . 62·9
(2) Serum—
(*a*) Percentage of plasma . . . . . . 89·7
(*b*) Percentage of whole blood drawn . . . **56·6**

TABLE XV.

ANTHRAX. DEFIBRINATION METHOD.

Buffaloes. *2nd Bleedings.*

Series	Volume of blood taken cc.	Volume of defibrinated blood obtained	Percentage yield of defibrinated blood	Serum		
				Volume obtained	Percentage of defibrinated blood	Percentage of whole blood drawn
1	3,200	2,400	75·0	1,800	75·0	**56·2**
2	2,900	2,250	77·6	1,750	77·8	**60·3**
3	18,400	15,050	81·8	10,000	66·5	**54·4**
4	3,200	2,200	68·8	1,500	68·2	**46·9**
5	16,400	14,100	86·0	8,400	59·6	**51·2**
6	24,300	20,700	85·2	13,000	62·8	**53·5**
7	1,900	1,550	81·6	1,100	71·0	**57·9**
8	15,000	13,300	88·7	8,100	60·9	**54·0**
TOTAL .	85,300	71,550	83·9	45,650	63·8	**53·5**

Average yields—
(1) Defibrinated blood . . . . . . 80·6
(2) Serum—
(*a*) Percentage of defibrinated blood . . . 67·9
(*b*) Percentage of whole blood drawn . . . **54·3**

TABLE XVI.

ANTHRAX. OXALATE METHOD.

Buffaloes. *2nd Bleedings.*

Series	Volume of blood taken cc.	Volume of plasma obtained	Percentage yield of plasma	Serum		
				Volume obtained	Percentage of plasma	Percentage of whole blood drawn
1	19,000	12,500	65·8	11,210	89·7	**59·0**
2	17,200	11,100	64·5	9,700	87·4	**56·4**
3	9,300	6,100	66·0	5,550	90·4	**59·7**
4	3,400	2,400	64·7	2,100	87·5	**61·1**
5	7,400	4,500	60·8	4,050	90·0	**53·3**
6	14,500	10,500	72·4	9,500	90·5	**65·5**
7	14,500	10,200	70·3	8,800	86·2	**60·6**
TOTAL .	85,500	57,300	67·0	50,910	88·8	**59·5**

Average yields—
- (1) Plasma . . . . 66·6
- (2) Serum—
  - (*a*) Percentage of plasma . . . . . 88·8
  - (*b*) Percentage of whole blood drawn . . **59·4**

TABLE XVII.

ANTHRAX. DEFIBRINATION METHOD.

Buffaloes. *2nd Bleedings.*

Series	Volume of blood taken cc.	Volume of defibrinated blood obtained	Percentage yield of defibrinated blood	Serum		
				Volume obtained	Percentage of defibrinated blood	Percentage of whole blood drawn
1	22,100	20,500	92·7	13,650	66·5	**61·70**

TABLE XVIII.

ANTHRAX. **OXALATE METHOD.**

Buffaloes. *3rd Bleedings.*

Series	Volume of blood taken cc.	Volume of plasma obtained	Percentage yield of plasma	Serum		
				Volume obtained	Percentage of plasma	Percentage of whole blood drawn
1	19,000	13,500	71·0	11,300	83·7	59·5
2	12,100	9,050	74·8	7,900	87·3	65·3
3	3,400	2,600	76·4	2,350	90·4	69·1
4	7,400	5,000	67·5	4,500	90·0	60·8
TOTAL .	41,900	30,150	72·0	26,050	86·4	62·2

Average yields—
(1) Plasma . . . . 72·4
(2) Serum—
(*a*) Percentage of plasma . . . . . . 87·9
(*b*) Percentage of whole blood drawn . . . 63·7

For comparison, the results obtained with anthrax serum are collected in Table XIX below :—

TABLE XIX.

ANTHRAX. **SERUM YIELDS.**

Animal	Nature of bleeding	Average yield of serum Percentage of whole blood drawn	
		Defibrination method	Oxalate method
Buffaloes	1st	48·6	56·6
,, ...	2nd	54·3	59.4
,, ...	3rd . . .	61·7	63·7

An examination of Tables XII and XIX shows at a glance that in every case the oxalate method gives higher yields of serum than the defibrination method. In the latter process the figures in the previous tables show that a much greater loss of blood takes place during defibrination than is generally supposed. As regards the oxalate method it is interesting to observe the surprisingly small amount of serum lost in the clot, the final yield generally amounting to about 90 per cent. of the plasma. Tables XII and XIX also show the influence exerted on the yield by the nature of the bleeding. The increased yields exhibited by 2nd and 3rd bleedings as compared with 1st clearly indicate a change in the blood composition and a series of analyses is at present in progress to determine the extent of this change. At the same time the blood changes in animals in process of immunisation against anthrax and hæmorrhagic septicæmia are being investigated.

In the description of the oxalate method given above in this paper attention was drawn to a striking difference between the blood of buffaloes and of hill bulls. In the case of the former the corpuscles settle almost at once whereas with hill bull blood but little separation takes place even in twenty-four hours. This difference is exhibited by the blood of both normal and immunised animals. A series of analyses has therefore been carried out with normal animals to see whether there might be any marked analytical differences between the two bloods which would account for this behaviour. The results are given below in Table XX.

The analytical data investigated and the methods employed were as follows :—

(1) Count of red cells. This was kindly carried out for me by Dr. G. H. Macalister, Pathologist in this laboratory, to whom my thanks are due.

(2) Estimation of protein in (*a*) whole blood, (*b*) corpuscles, (*c*) plasma. The corpuscles from a definite volume of blood were washed on the centrifuge with saline until free from serum, etc.

(3) Calculation from (2) of the relative proportions of plasma and corpuscles in the blood.

(4) Analysis of serum proteins :—
 (*a*) Total.
 (*b*) Albumin and Globulin.
 (*c*) Salt-insoluble proteins.

Total protein. This was calculated from the nitrogen content estimated by Kjeldahl's method.

Albumin and Globulin. The globulin was separated by saturation with magnesium sulphate and the nitrogen in the filtrate estimated.

TABLE XX.

Comparison of Buffalo and Hill Bull blood.

Serial number	Animal	Red cell count, Millions per cc.	Whole blood: Protein in 10 cc. grms.	Corpuscles: Protein in corpuscles from 10 cc. blood grms.	Plasma: Protein in 10 cc. grms.	Plasma: Volume of plasma in 10 cc. blood.	Serum: Total protein in 10 cc. grms.	Serum: Albumin in 10 cc. grms.	Serum: Globulin in 10 cc. grms.	Serum: Salt in soluble protein in 10 cc. grms.	Serum: Percentage of Albumin.	Serum: Percentage of Globulin.	Serum: Percentage of Salt-insoluble protein.
1	Buffalo	5·60	1·7650	1·2984	0·7219	64·6	0·6620	0·2756	0·3864	0·0471	41·6	58·4	7·2
2	„	5·35	1·7085	1·1813	0·7815	73·0	0·7284	0·3139	0·4145	0·2450	43·1	56·9	33·6
3	„	6·40	1·8230	1·2480	0·7937	72·4	0·7405	0·3380	0·4025	0·0974	45·6	54·4	13·2
4	,	6·10	1·7872	1·3200	0·7260	64·3	0·6695	0·3128	0·3567	0·0722	46·7	53·3	10·8
5	„	6·50	1·8342	1·3016	0·7613	69·9	0·7066	0·2931	0·4135	0·1258	41·4	58·5	17·8
6	„	5·80	1·5903	1·1189	0·7033	67·0	0·6355	0·2669	0·3686	0·0514	42·0	58·0	8·1
7	„	6·10	1·7992	1·3169	0·7218	67·0	0·6639	0·2855	0·3784	0·0591	43·0	57·0	8·9
8	Hill Bull	5·52	1·7850	1·2812	0·8090	62·2	0·7615	0·2735	0·4880	0·1520	35·9	64·0	19·9
9	„ „	4·72	1·6355	1·1233	0·7525	68·0	0·7284	0·2726	0·4558	0·1925	37·4	62·6	26·4
10	„ „	5·70	1·8390	1·2398	0·9078	66·0	0·9100	0·2986	0·6114	0·2767	32·9	67·1	30·4
11	„ „	5·32	1·5805	1·1058	0·6639	71·5	0·6355	0·2177	0·4178	0·0930	34·3	65·7	14·6
12	„ „	5·60	1·6986	1·1539	0·7941	67·4	0·7536	0·2428	0·5108	0·1531	32·3	67·7	20·3
13	„ „	5·07	1·5673	1·0259	0·7525	71·9	0·7120	0·2570	0·4550	0·1444	36·1	63·9	20·0
14	„ „	5·10	1·5695	1·1102	0·6650	68·1	0·6202	0·2286	0·3917	0·4703	36·8	63·2	7·6

Salt-insoluble proteins. These were removed by saturation with salt and estimations of the residual nitrogen in the filtrate then made.

All analyses were carried out in duplicate. The figures given on previous page, Table XX, are the mean results of closely agreeing experiments.

On examining the above figures it will be seen that there is practically no difference in the percentage of plasma in the two bloods, the average figures being 68·3 and 67·8 for buffaloes and hill bulls respectively. When one comes to the serum, however, a marked difference is at once apparent, the hill bull serum in every case containing considerably more globulin than buffalo serum. The average result expressed in percentages of the total serum protein was 56·6 for buffaloes and 65·1 for hill bulls. It is obvious that a change of this pronounced nature might very easily have a great influence on the physical properties of the blood. It has unfortunately been impossible at the present time to carry out any viscosity determinations but it seems likely that the difference in behaviour of the two bloods is due to this factor. Another interesting point is the extreme irregularity of the salt-insoluble protein content, a fact previously noticed by other observers. Meantime for convenience in working it is obviously desirable to employ as large a percentage of buffaloes as possible as in this way the volume of blood to be centrifugalised can be reduced to a minimum.

SUMMARY AND CONCLUSIONS.

(1) In the preparation of hæmorrhagic septicæmia and anthrax sera the oxalate method gives a considerably increased yield of serum as compared with the defibrination method.

(2) The serum prepared by the oxalate method is greatly superior in appearance to that obtained by defibrination and centrifugalisation.

(3) In the case of buffalo blood the oxalate method saves 50 per cent. of the centrifugalising as the corpuscles settle rapidly and the plasma can be syphoned off. This point is of considerable practical importance where large quantities of sera are dealt with as the consequent economy in engine power entails an appreciable saving of expense.

(4) With hill bull blood the corpuscles show little tendency to settle and the whole of the blood has to be centrifugalised as in the defibrination method.

(5) In both hæmorrhagic septicæmia and anthrax bleedings if a series of bleedings be taken at short intervals the yield of serum increases progressively, the third bleeding giving a larger percentage of serum than the second which in turn yields more than the first.

(6) Analyses of normal buffalo and hill bull blood show that the serum from the latter animal contains a considerably larger percentage of globulins than does that from buffaloes. This seems to be the chief point of difference between the two bloods.

In conclusion I wish to acknowledge the able assistance rendered me by Mr. G. P. Goffi, 2nd Laboratory Assistant. The misadventures so frequently consequent on the introduction of a new working method were almost entirely avoided owing to the careful way in which he supervised every stage of the process.

THE IMPERIAL BACTERIOLOGICAL LABORATORY,

MUKTESAR, UNITED PROVINCES.

October 10, 1915.

CALCUTTA
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Soil Aeration in Agriculture.[1]

I. Introduction.

The dominant factor in the internal economy of the Indian Empire is the monsoon. The well-being of the people, the commerce of the country and the revenue collected by Government all depend on the amount and distribution of the summer rainfall. It is not surprising, therefore, to find that the attention of the agricultural investigator in India tends to be concentrated on questions relating to the supply of water to crops. At the same time, the other factors on which yield depends are apt to be obscured and crop-production comes to be regarded almost entirely as a question of water-supply. After ten years' observation of the crops grown on the Indo-Gangetic alluvium, during which a good deal of first-hand experience in agriculture has been obtained at Pusa in Bihar, at Lyallpur in the Punjab and at Quetta in Baluchistan, the conclusion has been reached that a full supply of air in the soil is quite as important as a sufficiency of water. While air is a necessary raw material for the soil organisms and for the roots of plants wherever they may be grown, efficient soil-ventilation is found in practice to be particularly difficult on alluvial soils like those met with over large areas of the plains of India. Alluvial soils, like those of the valleys of the Ganges and Indus, pack very readily and always run together on the surface after heavy rain, forming a well-defined crust, well-known to any cultivator as the *papri*. Two chief factors are responsible for the ease with which these alluvial soils form surface crusts after light showers and lose their porosity altogether after long-continued rain. In the first place, the soil particles are small in size and exhibit no very great range in diameter and, in the second place, much of the rain comes in heavy continuous torrents quite unlike anything experienced in temperate regions. On many of the soils of Peninsular India, the aeration difficulty occurs chiefly in the monsoon due to the expansion of these soils as a whole when thoroughly wetted. In the *rabi*, there is abundant aeration due to cracking.

[1]A lecture delivered on February 7th, 1916, during the meeting of the Board of Agriculture at Pusa.

The enormous losses in fertility caused by water-logging during the monsoon will be evident from an experiment carried out at Pusa in 1910. A plot of wheat land was water-logged during September and the produce was compared with that of normally drained plots. The result was a fall in yield of 16 bushels of wheat to the acre. That this was largely due to denitrification following water-logging is proved by the increased yield obtained on the shaded strip of land running down the middle of the plots which was manured with nitrate of soda at the rate of 4 cwt. to the acre. Nitrate of soda had little effect on the yield on the normally-drained plots. On the water-logged plot, however, the outturn was increased by 10 bushels of wheat to the acre.

The result of water-logging wheat land at Pusa in 1910.

Normal cultivation.	Waterlogged during September.	Normal cultivation.
34·45	15·55	29·14
SHADED AREA TREATED WITH 4 CWT. NITRATE OF SODA PER ACRE		
35·92	25·17	26·53
34·45	15·55	29·14

The numbers in the plan are bushels per acre.

Defective aeration of the soil, besides interfering with the respiration of the active cells of the root and of the soil bacteria, exercises a profound influence on the development of the root-system itself. Where the subsoil is wet and consolidated and gaseous interchange between the soil and the atmosphere has been checked, crops are found to develop superficial roots only and are then particularly liable to the harmful

effects of drought. To withstand any shortage of moisture, to make the most of the brief growing season and to ripen the crop before the onset of the hot weather, the root-system of all *rabi* crops must be deep. In the *kharif*, long-continued and heavy rain, by destroying the porosity of the soil and by thus interfering with the air-supply to the roots leads to a wilted, poverty-stricken condition of the crops and to a diminished yield. Such examples of damage to monsoon crops, caused by excessive rain interfering with aeration, were common in many parts of the United Provinces during the later phases of the 1915 monsoon.

Fig. 1 Growth of barley in solutions aerated once a day (left) and aerated continuously (right).

That root-development depends on aeration will be clear from a study of one of Mr. Hall's papers published in the sixth volume of the *Journal of Agricultural Science*. One example taken from this paper

will suffice. On the screen are represented two water cultures of barley. The bottle on the left was aerated once a day, that on the right was aerated continuously. It is clear that both root-development and growth depend on the amount of aeration.

Such examples as those of Mr. Hall can, however, be observed in the field and there are many to be seen in the Botanical Area at Pusa at the present time. The most interesting is linseed. Linseed is a crop which is exceedingly sensitive to a wet sub-soil and wilt easily takes place from this cause. This year the sub-soil in Bihar contains too much moisture and too little air. In such seasons, linseed grown on land subjected to the drying effects of the roots of leguminous trees does better than on ordinary land. The tree roots remove some of the excess water from the sub-soil. Air then takes the place of this water and the roots act indirectly as aerating agents. Java indigo, grown for seed, often behaves in the same way. A similar state of things sometimes occurs in tea in Assam and Ceylon where the best bushes are found on land within the radius of action of leguminous tree roots. In all such cases, increased surface drainage is of course indicated as the best means of improving these gardens.

II. Some Examples of Soil Ventilation.

Among the numerous instances observed of the effect of improved soil-ventilation on the growth of crops it will be sufficient if we consider a few examples.

1. *The yellowing of peach trees.* As you are aware, the Quetta valley has a reputation for its fruit and for the size and quality of its peaches. Some of the trees, however, particularly those in the Civil Station, are not healthy although they bear fruit every year. As the summer progresses, the foliage of many of these peach trees alters in colour and changes first to light-green and finally to yellow. Premature leaf-fall then takes place, and, by the end of August, many of the branches are almost bare of leaves. In addition to the yellowing of the foliage, two other symptoms manifest themselves. The wood gives off large quantities of gum and the ripening fruit is deficient in flavour. Peach trees affected in this way die out in two or three years, the process taking place in stages by the death of one or two large branches at a time. The yellowing might be due

to one or more of the following causes—(1) a deficiency in available nitrates, (2) a disease similar to the peach yellows of the United States or (3) poor soil-aeration. Investigation of the trouble showed that the unhealthy condition was not caused by want of available nitrogen in the soil as the application of nitrate of soda and sulphate of ammonia had no effect. It was not a disease of the nature of the peach yellows of the United States as buds taken from affected trees produced healthy plants and therefore the unhealthy condition was not transmitted in propagation. Yellowing was found to be reproduced at will, either by deep-planting or by over-irrigation and it proved to be a result of poor soil-aeration. Any effective method of aeration was found to transform affected trees into a healthy vigorous condition in a single season. Yellowing and the premature death of the peach trees at Quetta was therefore found to be the result of defective aeration of the soil caused by excessive surface-flooding under arid conditions. I have dealt with this subject of the yellowing of peach trees at Quetta in more detail in Bulletin No. 3 of the Fruit Experiment Station, Quetta, so that anyone interested in the subject can find further details there.

2. *The relation between soil-aeration and the growth of pod-bearing (leguminous) crops.* The copious aeration of the soil, in which leguminous crops are grown, is perhaps more important than in any other class of cultivated plants. As is well known, this class of crops have numerous swellings, known as nodules, on their roots by means of which they are able to make use of the nitrogen of the air. Besides nitrogen, these crops require oxygen as well for the respiration of the roots themselves. Once these facts are realized, it is easy to understand the distribution of leguminous crops in India and the agricultural processes in vogue in their cultivation.

Let us consider the gram crop of which about 18,000,000 acres are grown in India every year. On the screen is a table showing the area under this crop in the various parts of India (Table I). The greatest acreage is in the Province of Agra, in the Eastern Punjab, in Central India and in parts of Oudh. It is less important in Bihar, Bengal and on the canal-irrigated areas of the Punjab and Sind. The distribution of gram follows the occurrence of well-aerated soils. It is a crop which can only be grown successfully under irrigation in cases where flooding the surface does not destroy the porosity of the soil. We can irrigate gram to advantage on the open sandy loams of the Meerut Division or on the soils of the Bombay Deccan underlain by the porous substratum known as *murrum*. We cannot, however, irrigate gram to

advantage on the stiffer soils of the Chenab Colony or in Sind or on the heavy loams of Oudh and Bihar.

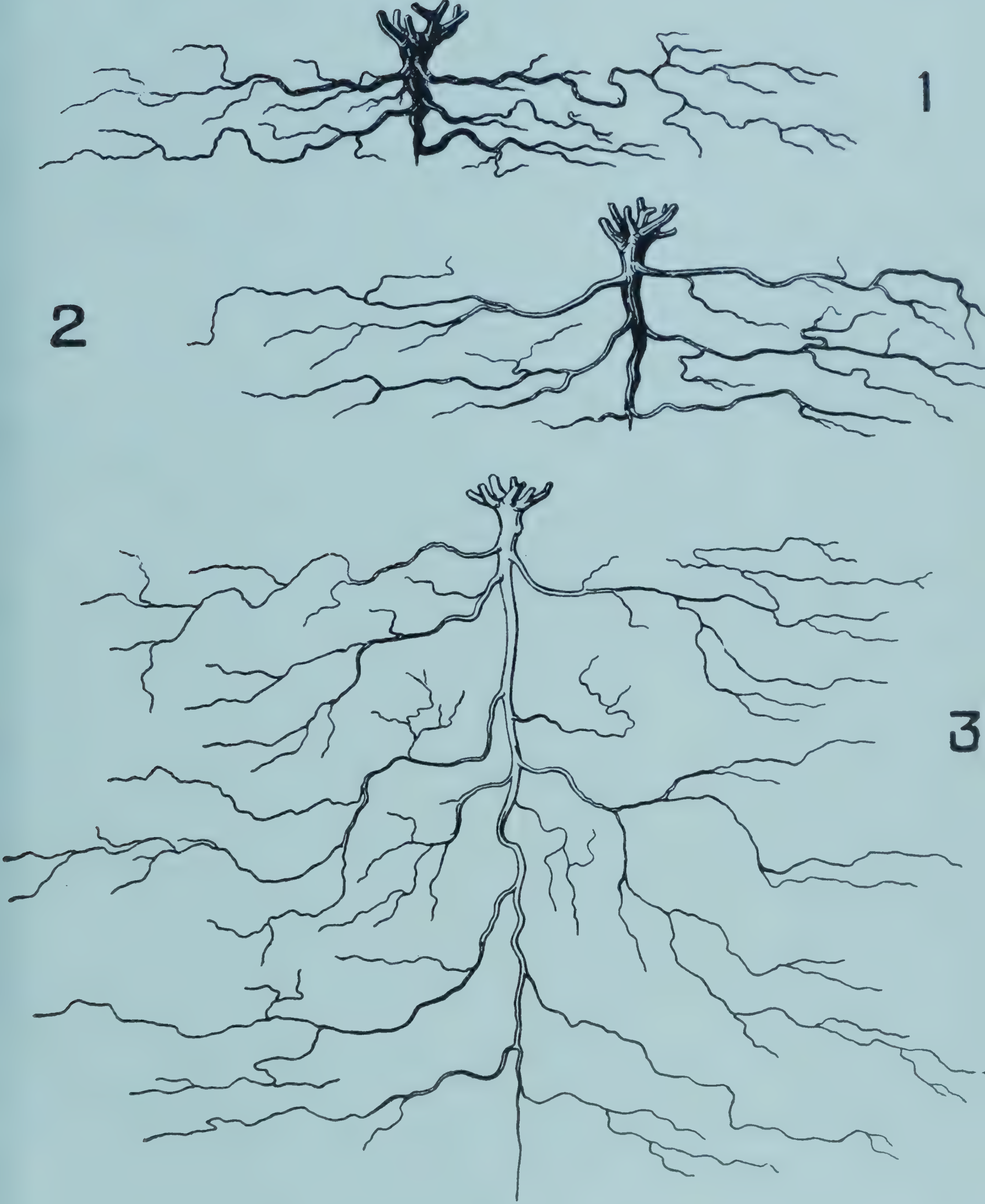
TABLE I.

Area and average yield of gram in 1911-12[1].

Province	Area (in acres)	Yield (irrigated) in lb. per acre	Yield (unirrigated) in lb. per acre
Assam	905	..	..
Bengal	176,700	..	881
Bihar and Orissa	892,100	..	881
Oudh	1,697,097	950	800
Agra	5,175,443		
Punjab	4,099,894	625	534
North-West Frontier Province	174,119	730	449
Sindh	76,439	476	..
Bombay	422,274	1,200	420
Central Provinces	993,113	..	532
Berar	117,221	..	..
Madras	134,900	..	..
Upper Burma	38,905	..	414
Lower Burma	1,377	..	..
Ajmer Merwara	26,176	..	..
Coorg	1,540	..	..
Pergana Manpur (Central India)	678	..	..
Total—British India	14,128,881	Average yield 688 lb per acre.	
Total—Native States	4,039,929		
GRAND TOTAL	18,168,810		

[1]*Agricultural Statistics of India for the years* 1907-08 to 1911-12, Calcutta, vol. 1, 1913, pp. 120 and 387.

PLATE



SOIL-MOISTURE AND ROOT-DEVELOPMENT.

The results of some recent experiments at Pusa explain the geographical distribution of gram in India and the factors on which yield depends. I will now refer only to those which deal with the roots and nodules. On the screen (Plate I) is a representation of the root-system of three gram plants grown in the same year at Pusa within one hundred yards of each other but on different classes of soil. The upper sketch shows the root-system developed on a heavy loam. Here the crop did very well up to flowering time but it set no seed and wilted away. The lower figure shows the root-system of a gram plant in light land. Here the yield of seed was heavy. The middle drawing shows the root-system in land intermediate in character. Here the plants did not set seed well and the yield was poor. Yield in these cases depended on the depth of the root-system and on the development of nodules which are, however, not shown in this slide.

That the depth and extent of the root-system depends on the aeration of the soil will be clear from the next two slides (Plate II). The first represents two gram plants just in flower taken from two adjoining plots which have been treated uniformly for the last ten years. There is, however, one difference between the plots. The soil of one contains in the first foot about 50 tons of *thikra* to the acre, the other contains little or no *thikra*. *Thikra* is the Hindustani word for potsherds or tile fragments. The different development of the plants in these two soils is evident. The presence of the *thikra* ensures copious aeration and this in turn leads to the extended and rapid development of the roots and root-nodules. The greater the growth of root, the better the development of the above-ground portion of the plant.

In the next slide (Plate II) are two gram plants of the same age and variety taken from the same plot and from places a few feet apart. The best developed plant grew at the western end of the plot and within the root range of some *sisoo* trees which were cut down two years ago. White ants have now eaten out the wooden cores of these roots leaving a system of under-ground tubes in their places. These promote aeration, which in turn leads to increased root-development and growth of the gram plant.

The last slide relating to gram (Table II) deals with the relation between yield and root-development. In a wet year, we should expect that the consolidation of the upper soil (by preventing aeration) would tend to lower the yield of deep-rooting, late varieties. That this is so is shown by comparing the root-range and yield of three varieties in 1915, a very wet year. These three varieties yield about the same in a season of good sub-soil aeration but, in the wet season of 1914-15, the yield was inversely proportional to the depth of the root-system.

TABLE II.

The relation between yield and root-development in a wet season.[1]

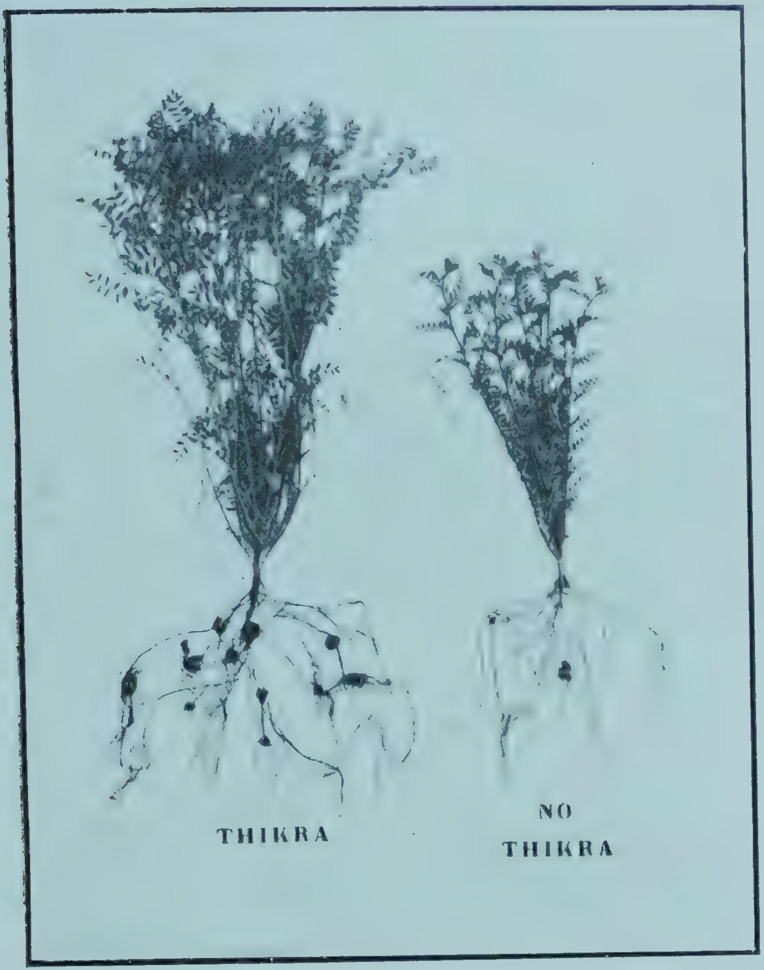
Variety	Date of flowering	Average length of tap-root bearing laterals	Area, in acres	Yield per acre, 1915		Yield per acre, 1912	
				m.	s.	m.	s.
Type 9	Feb. 18th	16 cm.	1·5	12	22	32	16
Type 17	Feb. 4th	13 cm.	1·0	18	9	30	31
Type 18	Jan. 18th	8 cm.	1·0	23	27	34	27

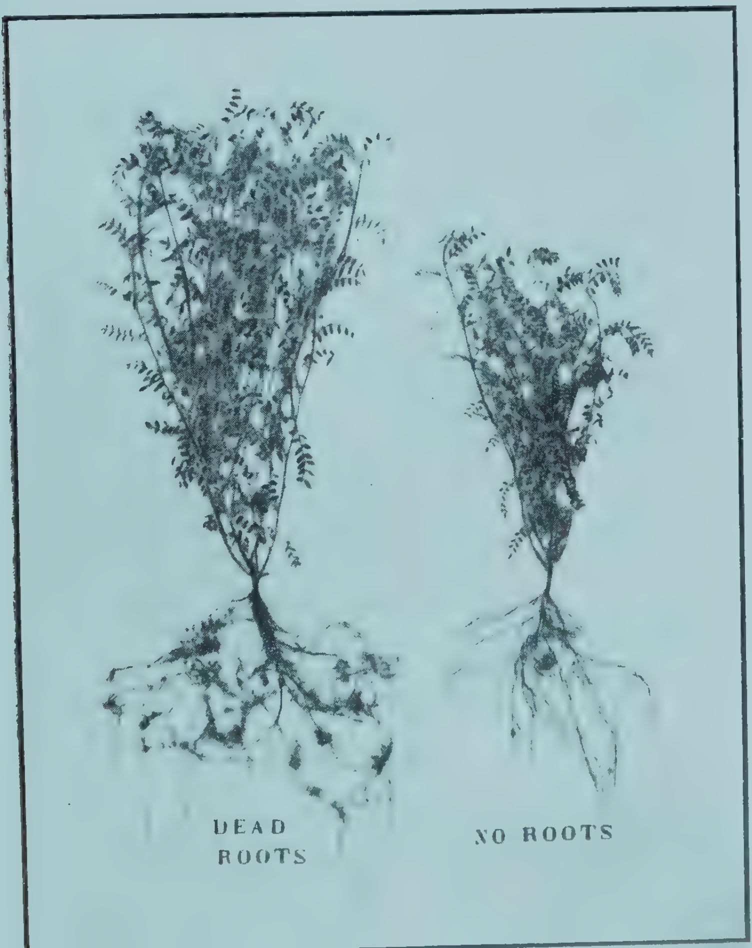
These results show clearly the close correspondence between soil-aeration and growth in the case of the gram plant and they also enable us to understand the present geographical distribution of gram in India. They also throw light on one of the great causes which limits the yield, namely, long-continued wet weather. This causes the surface soil to run together and to form a crust through which the roots and nodules cannot get sufficient air. The result is a gradual wilting of the crop.

Another example of a leguminous crop with root-nodules is Java indigo. This plant is perhaps the best instance that can be quoted of the close relation which exists between the degree of aeration in the soil and the development of the crop. The slightest interference with the air-supply at once makes itself manifest by leaf-fall or by the shedding of flowers without setting seed. If the air-supply is partially cut off through any cause, the plant loses a number of its nodules and feeding roots at once and it proceeds to adjust its leaf-surface to the diminished root-range. The lower, older leaves are shed first. If the interference with the air-supply of the roots and nodules proceeds, as it often does during a well-distributed monsoon, more roots are destroyed, the supply of water and food materials from the soil falls off, the leaf-surface at the same time is progressively reduced and at last the plant begins to die. Death takes place in stages and the branches wilt off in succession. The planters recognize this moribund condition of Java indigo and speak of it as wilt. Wilt in indigo is the last phase in starvation

[1] A result, such as the above, brings out the importance of detail in variety trials in India. But for the determination of the depth of the root-system, the reason for the reversal of the 1912 results in 1915 would not have been evident.

PLATE II.





of the plant and can be produced by interference with the air-supply of the roots and nodules.

Before dealing with the remedies which have been found successful in the case of wilt, I should like to compare the preparation of indigo from the plant (natural indigo) with the manufacture of the dye in the German factories from coal tar products (synthetic indigo). The two processes are shown on the screen (Fig. 2). The factories where artificial indigo is made are marvels of organization and of the application of brains and chemistry to industrial ends. The processes in making synthetic indigo are long, complex and costly but the product is uniform and easy to use. Largely on this account, it has established itself in the markets of the world. In the case of the production of natural indigo, the plant, by means of its root-nodules, is able to work up the nitrogen of the air into the substance *indican* which is deposited in the leaves. The crop is cut, soaked in water and cakes of natural indigo are produced.

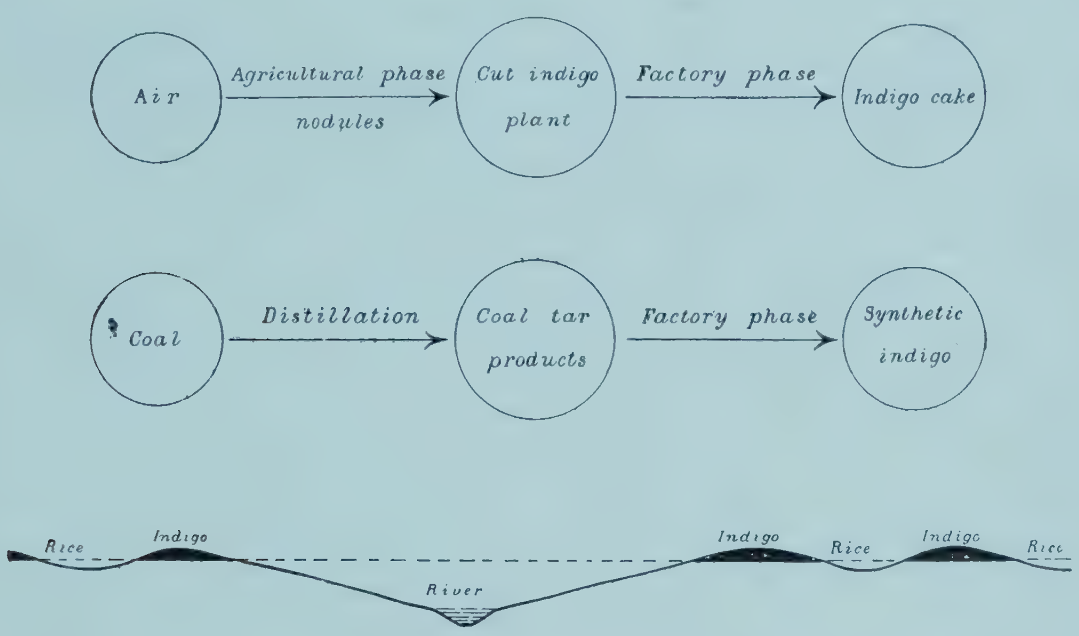


Fig. 2. The natural indigo problem.

From 1898 to 1913, attempts have been made to improve the production of this dye and over £50,000 have been spent in the attempt. No results have been obtained for the simple reason that the chemists employed in the work began at the wrong end and practically ignored the indigo plant. They attempted to improve the factory processes and to increase the yield of dye. The real problem, however, is to be found

on the agricultural and botanical sides and is concerned with the working of the plant as a living machine. Given the most efficient type of indigo for Bihar conditions, all that is necessary is to raise good seed and to see that the roots and nodules get plenty of air. Let us see how this can be done. Along the lower edge of the screen (Fig. 2) is shown a section through Bihar at right angles to the rivers. The country consists of alternate low-lying rice *chaurs* and high-lying folds on which Java indigo is cultivated and on which the indigo factories are to be found. In the cold weather, the rivers are low but during the monsoon the water-level rises and all the country becomes more or less water-logged except the crests of the ridges. About once every four years, there is a flood and some of the ridges go under water. The high-water mark is said to be slowly rising at the rate of about three inches a year. The result is that there is less and less air in the soil and more and more indigo is killed for Java indigo, as we should expect, is rapidly destroyed by inundation. Experienced planters say that the rise in the water-level in the monsoon is caused by embankments (canal, rail and road) which interfere with the flow of the flood-water and also help indirectly to silt up the water-ways. I have no hesitation in saying that they are right. It will be easy now to see why the plant has so far lost in the contest with the German factories—on the one side, ample raw material and efficient organization ; on the other, constant interference with the air-supply to the roots and nodules, a plant with varying amounts of indican and a final product of varying dyeing power. Let us see what help aeration can give in re-establishing the industry. Three lines of work are indicated.

(*a*) Seed supply. The first thing is to ensure the seed supply. This has been done and results are beginning to appear on the indigo estates. Still better methods have recently been devised which are now being tried on an estate scale. The problem of the seed supply is an aeration problem as will be seen if the seed indigo crops shown on the next two slides are compared. The first shows indigo sown on a slight fold with exceedingly good surface-drainage. The plants are tall, well-grown and they carry a heavy crop of seed. The second slide shows the same variety, sown at the same time on another plot where the natural drainage was not so good. Here the plants are short, somewhat stunted and the amount of seed is small. The photographs were taken at the same distance from the camera. We are now treating the land for indigo seed with *thikra* and I have little doubt that the large scale

demonstrations on the Dholi estate will serve instantly to establish this new method.

(*b*) Improvements in the aeration of the soil during growth by cultivation and surface drainage. These improvements have been dealt with in the first and second indigo reports and need not be described in detail here. It is sufficient to say that they have proved successful under estate conditions and are being taken up rapidly all over Bihar.

(*c*) Improvements in the drainage of North Bihar as a whole. This the most important method of all, is being taken up by the Hon'ble Mr. Morshead, Commissioner of the Tirhut Division. A drainage map of this tract will be prepared on which the various embankments interfering with the natural drainage of the country will be marked. With this drainage map as a basis, it will be possible rapidly to deal with the whole tract in a comprehensive manner and to lay the foundations on which the natural indigo industry can be regenerated and the producing power of Tirhut at least doubled. A successful scheme in North Bihar will do more than this. It will probably lead to the preparation of similar drainage maps in other parts of India which is the real basis on which the economic development of the country can best be undertaken.

3. *Soil-aeration and green-manuring*[1]. The provision of some cheap form of organic matter is one of the great needs of Indian agriculture at the present time. As is well known, the amount of manure available is small due to the fact that almost all the *bhusa* is used for feeding cattle and most of the cow-dung is burnt as fuel. As a rule, Indian soils are deficient in organic matter and the yield is limited by this factor. One theoretical method of making up the deficiency is by green-manuring but, in practice, difficulties arise. A considerable amount of attention has been paid to this subject in the Botanical Area at Pusa and the conditions necessary for the success of this operation have now been worked out. If a crop like *sanai* (*Crotalaria juncea*) is raised on the early monsoon rains and ploughed in during July, it is found that the texture of the soil is improved and, in a few cases on light land, the succeeding *rabi* crop benefits enormously by the addition of the organic matter left by the decay of the green crop. In the majority of the Bihar soils, however, these

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[1]The earlier results on green-manuring are referred to in detail in the *Agr. Jour. of India*, vol. VII, 1912, p. 80 and in Bulletins 51 and 52 of the Agricultural Research Institute, Pusa.

results are not obtained and the *rabi* crops following green-manure are much worse than those raised on ordinary fallowed land. Ordinarily, green-manuring leads to a diminished *rabi* crop although the process results in the addition of a considerable amount of organic matter to the soil. After some years' experiment, it was found that the factors on which success in green-manuring depends are connected with the air-supply in the soil. The addition of a green crop to the soil adds another formidable competitor for oxygen with the result that, in badly aerated soils, oxygen becomes a limiting factor in growth. If the land is surface-drained and if provision is made so that each field is protected from the run-off of other areas by a suitable arrangement of trenches, the effect of a green-manure crop is materially increased. If, in addition, the land is subsoiled to a depth of twelve inches before the *rabi* crops are sown, still better results are obtained. When broken tiles (*thikra*), at the rate of about 50 tons to the acre, are mixed with the upper six inches of soil, the results are exceedingly striking and a maximum crop can easily be obtained by green-manuring alone.

The final results of the green-manuring experiments with tobacco, in which *thikra* has been added to the soil, will not be available for some time. Practical planters and cultivators who have seen the preliminary experiments are convinced that the maximum tobacco crop can be grown with green-manure alone on drained land treated with *thikra*. The experiments are most conclusive and there is no doubt that, given sufficient moisture in the soil for decay, the factor on which green-manuring depends in India is abundant soil-aeration. Aeration also explains why green-manuring on the open sands of North Germany has been so successful. These soils are of such a texture that they aerate themselves. On the plains of India, we must overcome poor aeration by drainage and *thikra*. In future in India, the cultivator will go on burying his savings as before not however as rupees but in the form of a permanent manure—*thikra*. In this manner, silver can be transmuted into gold and the dreams of the old alchemists will become a reality. The philosopher's stone is a potsherd.

4. *Aeration and field experiments*. Just as increased aeration means better root-development and better growth so diminished aeration leads to a poor yield. Water-logging during the monsoon and the absence of surface drains are the chief causes of poor soil-aeration and poor root-development. Examples are to be seen everywhere and were particularly well marked a few years ago on the old manurial plots and variety trials at the Government Farms all over India.

I never saw one of these series that was not ruined by obvious want of drainage and by water-logging. The aeration factor was almost always greater than any difference in the yielding power of the varieties or of the manures. The worst cases I saw were those in which green-manuring had been attempted. The results were true, they showed the harmful effect on the next crop when green-manure is put into imperfectly aerated and badly drained land.

III. Maturation and Quality.

Besides its influence on the actual growth of crops, the provision of an abundant air-supply appears to be bound up with the ripening processes and with the development of quality.

1. *Wheat.* In the case of the wheat crop, the best grown samples are always produced in tracts like the Meerut Division of the United Provinces or on the black soils of Central India, where the soil in the *rabi* season is naturally highly porous. In Bihar, Oudh and in parts of the Punjab, where surface flooding interferes with aeration, the grain is always much thinner in appearance particularly in years when the rainfall is heavy during the ripening period. Unless the wheat roots get plenty of air during the process of maturation, the sample is always relatively poor in appearance.

2. *Barley.* Aeration also explains the difference in malting barley grown on different soils in England. For malting, the barley grain must be well-filled with starch so as to produce a rich malt-extract. Such barleys are always grown on light land where the natural aeration of the soil is good. Here barley ripens off quickly and such soils are called sharp soils by the English farmers. On stiffer soils, the aeration is bad, the barley ripens slowly and the grains are often poorly filled with starch. Malsters do not like these barleys as they give a thin, cloudy malt-extract.

3. *Peaches.* Anyone who has studied the peach tree and has attempted to grow this fruit to perfection must have been impressed by the difference in quality of the same variety when grown on soil a little heavier than the normal. As is well known, the peach thrives best on open soils and is particularly sensitive to any form of water-logging or poor aeration. Some years ago, the Botanical Section at Pusa achieved a local reputation on account of the excellence of the peaches grown there. The varieties were only country kinds but they

were grown on high land containing a fair proportion of broken tiles (*thikra*). The soil was thus highly porous and the roots obtained abundance of air. The quality of the fruit was excellent compared with the produce of similar trees on land close by a little heavier in texture which contained no *thikra*.

4. *Vegetables and flowers.* In the growth of vegetables and flowers, some of the soils of Lucknow are famous. The best produce is raised under irrigation on the highly-manured sands near the banks of the Gumti. The soils in themselves are poor but, when properly manured and watered, their porosity is so great that surface-flooding causes little or no damage to their texture. The roots of the vegetables and flowers thus obtain abundant air and grow to perfection. The vegetables have excellent taste while the flowers easily form a quantity of good seed. Here again the development of quality seems to be closely associated with soil-aeration.

5. *Tobacco.* A similar result is seen in tobacco growing in Bihar. The best tobacco is grown on high, light lands which have been manured with indigo *seeth*. The *mahajans* pay more for such produce and several of the indigo factories have a reputation for their tobacco. *Seeth* is undoubtedly a most efficient aerating agent and all the experience obtained at Pusa in the growth of tobacco points to the great importance of soil-aeration in the ripening of this crop. Once more, maturation appears to be closely bound up with the ventilation of the soil which again appears to be of supreme importance in the development of quality.

I have quoted only a few examples out of many that might be mentioned. There is little doubt that the two chief factors on which the quality of any agricultural product depends are (1) the variety and (2) the aeration of the soil.

IV. Some Practical Applications.

It is not proposed, in this lecture, to spend any time on the scientific discussion of the manner in which aeration affects the plant, the soil and the organisms in the soil. This was dealt with in a paper read at the Indian Science Congress at Lucknow and will appear in print in due course. Instead, the practical applications of soil-aeration will be briefly considered. These applications are so numerous and the far-reaching effects of the ideas put forward in this lecture are so

extensive that it will not be possible to do more than indicate the enormous progress that will now be possible in agriculture both in India and in other countries.

1. *The wider aspects of drainage.* I want you first to consider the Indian rivers. The river systems of India are the great drains on which the welfare of the crops depends. These carry off the surplus rainfall and, in so doing, materially assist in aerating the soil. But for the existence of these rivers, a vast portion of India would be a pestilential swamp. These rivers not only take off water but they also carry a load of silt. If the velocity of flow is checked or if any impediment is placed in the channel, two things happen—firstly, water is held up and soil-aeration is interfered with and secondly, the river begins to deposit its silt and to raise its bed. Both are harmful to the well-being of crops. It is a curious circumstance that the rivers of India have not been studied in any detail and that no monographs exist on these great natural drains, on the efficiency of which the material prosperity of India depends. Neglect of such studies has led to serious damage to the country in the construction of canals, railways and roads which often block, to a great extent, the high-flood channels and, by checking the flow, compel the rivers to deposit silt and to raise their beds. When a railway or a road has to be carried across a river, an earthen embankment is often run across the high-flood fair-way as far as possible and a little bridge in the middle is put in to save expense in iron-work. Economy in construction is a most important consideration in India but, taking the long view, it is a small matter compared with the partial blocking up of one of Nature's drains. All over the plains of India such examples as I have indicated are to be seen. Sometimes, the floods punch a hole in the raised embankments and traffic is suspended till an army of coolies can be collected to mend up the breach with earth or to put in a few small culverts. Sometimes, these breaches occur continually as on the railway from Ruk to Sibi on the North-Western line. These occurrences are merely a proof of defective alignment and of defective construction. When a railway has to run across a broad, shallow drainage line, it might pay to lay it flat and to let the water run over it. At the most, the interruption to traffic would not be a very long one. The only other alternative is the provision of copious water-ways, underneath the embankment, which are very expensive.

It is only fair to say that these mistakes are not universal and do not occur in the case of bridges over the large rivers such as the Ganges,

the Jumna and the Gogra which, in the monsoon, are streams much too powerful to be trifled with by such flimsy contrivances as earthen embankments thrust across their courses. The great damage is to be seen in the case of the smaller and less powerful rivers and in the minor drainage lines of the country-side.

The remedy for this state of affairs is to recognize the great importance of the rivers and drainage lines in the internal economy of India and to construct proper drainage maps. These will immensely strengthen the Executive when dealing with new projects and will at once put an end to a large amount of damage now being done to India. In the drainage map, the Executive would possess a powerful means of control.

The local aspects of drainage have been dealt with in Pusa Bulletin 53 and the subject will be discussed at the present meeting of the Board of Agriculture. I will not attempt to anticipate the result of these deliberations.

2. *Irrigation.* The first impression the student of Indian agriculture experiences in studying the development of the irrigation systems of India is one of admiration. The canal systems of this country are famous throughout the world and large areas of the country are protected from famine. Minor projects, such as inundation canals and tanks, are abundant while, in well-sinking, Government often advances the capital and provides engineers to devise efficient power plants which, at small cost, increase the value of a tube well many times. Irrigation in India has been regarded by Government in a broad way in so far as the provision of water is concerned.

There is, however, another side to the question, namely, the welfare of the plant. It must be confessed that in this direction there is room for development and for the accumulation of reliable data on which a sound and economic irrigation policy can be based. A study of the wheat crop in many parts of India has convinced me that, not only is there an enormous waste of valuable water going on but the crop is being positively harmed by too much irrigation. Thus at Quetta in Baluchistan, it has just been proved that, on every hundred acres of irrigated wheat, the amount of water annually lost would produce wheat and *bhusa* worth half-a-lakh of rupees. Wheat and other irrigated crops must have plenty of air in the soil and if this is not provided, the root-development is poor, the crops easily suffer from drought and can only be ripened by the expenditure of large volumes of water. In many parts of India, I feel sure that good wheat crops can be ripened

on a single irrigation applied just prior to sowing. This will cool the soil, will help in the production of a deep root-system and will at the same time supply ample moisture. Two irrigations at the most ought to be enough in the rest of the irrigated tracts except on the sandier soils like those in the Western Districts of the United Provinces. I have dealt with this subject in detail in a paper in the current issue of the *Agricultural Journal of India*[1] so that no more need be said now.

3. *Manuring.* Once the part played by aeration in crop-production is realized, the current ideas underlying manuring will have to be considerably revised. While the application of chemical and other manures has undoubtedly increased production, its very success has worked a considerable amount of mischief and has done much to obscure the real factors on which growth depends. I will confine my remarks to nitrogen and phosphorus, the two substances on which vast sums are now spent or rather wasted.

Nitrogen is applied to the earth either as a chemical (sodium nitrate, sulphate of ammonia or some similar substance) or in the form of organic matter. The best results are obtained by means of the organic nitrogen manures as these increase the porosity of the soil and help in soil-aeration. Indigo *seeth* is the most effective form of organic nitrogen known to me. Now all this expensive nitrogen manuring is largely a mistake. The soil possesses the most efficient nitrogen producers known to science. These are the nitrogen producing and the nitrogen fixing bacteria which require for their work organic matter (such as green manures or farm-yard manure), air and water. Why purchase, at a great price, the fleeting benefits of nitrogenous manures when by draining the land and adding substances like *thikra*, a crop of green-manure will supply everything that is necessary ?

Much the same state of affairs exists with regard to phosphates. Phosphates often increase the crop but, in many cases, the results are misleading. It is the fashion to say, in cases when the effect is beneficial, that the soil contains insufficient phosphates in an available form. Why is this ? The answer is to be found in the mycological domain, in the beneficial activity of the soil fungi. These collect phosphates and potash for the higher plants but they cannot do this adequately unless the soil is well supplied with air. Drainage is perhaps the best and cheapest form of phosphorus just as *thikra* is the best nitrogenous manure.

[1]*Agr. Jour. of India*, vol. XI, 1916, p. 14.

4. *The improvement of varieties.* There can be little doubt that in the improvement of the variety and in the re-creation of the types of crop now cultivated. India offers great scope for the plant-breeder. Want of aeration in the soil, however, is the great bar to progress and, until this is removed, comparatively little can be accomplished. All high-yielding and drought-resisting varieties are deep-rooted. Deep-rooting is impossible under the present system of irrigation and in the absence of good surface-drainage. In the present semi-water-logged condition of great tracts now under irrigation, the best results are obtained with surface-rooted, low-yielding kinds. Once we reform the present methods of applying water to land, once we improve the rivers and provide a system of surface-drainage in the monsoon-fed tracts, the way will be opened for deeper rooting and high-yielding kinds. I will give a single instance of the relation between the choice of varieties and the condition of the subsoil as regards air. When in 1908, I completed the classification of the wheats of the Punjab, I found the zamindars near Lyallpur liked a wheat they called the *Lal kasar wala* (the red awned sort) which is a shallow-rooting, early variety which was included in the classification as Type 11. This is one of the wheats now being distributed by the Agricultural Department. Now when grown on properly aerated land, several of the other Punjab wheats yield more than Type 11 but not under cultivators' conditions. Here the deep-rooting kinds are suffocated by surface irrigation before they can ripen. Surface-rooted, early kinds like Type 11 are suffocated less and so give the best results. The limiting factor in the growth of wheat on the Chenab Colony is air not water.

5. *The improvement of cattle.* One of the great problems connected with the improvement of cattle and buffaloes in India is the supply of sufficient food. Many excellent breeds of these animals exist but, it often happens, that the food-supply is short. Given more food and better food, a great improvement would at once take place among the work-cattle in India as well as among the cows and buffaloes. Now this is largely a matter of soil-aeration. Improved drainage and aeration, combined with an adequate supply of organic matter, will at once increase the fodder supply per unit of area as has been found already at the Fruit Experiment Station at Quetta and in the Botanical Area at Pusa.

I will now consider a few of the crops of India and will attempt to indicate how they can be improved on the basis of better soil-aeration.

6. *Wheat.* Given a soil of the proper texture with sufficient moisture, the future of wheat-growing in India is largely a question of soil aeration. This we have discovered as one of the secondary results of the environment experiments, in which the same variety of wheat has been grown under widely varying conditions and the resulting samples compared. Where the soil aeration is good, we get the best ripened samples. Where the aeration is bad, we get the worst grown wheat. In the Botanical Area at Pusa, there is a plot on which wheat has been grown continuously without manure for eight years. There is no loss in fertility except on the north side where the plot is now being invaded seriously by the roots of trees. The results of the permanent wheat plot at Pusa are simple aeration effects. The plot is surrounded by surface drains, the aeration is therefore good and in turn the supply of nitrates and phosphates is abundant. In this direction, we have possibilities of improvement in wheat production which will settle the food supply of the world for generations to come. We need pay no attention to the warnings of the late President of the Royal Society (Sir William Crookes) or to the proposals in a recent issue of *Nature* for a committee to consider the manufacture of nitrates from the air for manuring wheat. Supply air by drainage and other means and the wheat-growing surface of the world becomes of itself a vast nitrate and phosphate-producing factory. The agents producing the nitrates are the soil bacteria. The phosphates are collected by the soil fungi.

In Bihar and in other parts of India, in addition to air we have another factor to consider—soil temperature. If the soil is too hot, wheat and other *rabi* crops will not thrive. We get the best wheat and *rabi* crops in Bihar in years when the sowing rains (*hathia*) come. These rains cool down the whole country and all the *rabi* crops develop a deep root-system and we get bumper crops. When the *hathia* fails, the crops are poor except tobacco which likes a hot soil. Last year, I discovered that by opening the lands at sowing time to cool them and by late sowing we can do without the *hathia* and get good crops. This year the experiment was extended to 300 acres of wheat on the Dholi estate. Although much of the wheat sown in the district failed altogether, one of the finest crops ever grown in Bihar is to be seen at Dholi. The practical application of the principle of artificially cooling the soil will give the Dholi estate an increased profit of at least Rs. 10,000 on a single crop in a single season. The same principle can be applied in the irrigated tracts and particularly in the Central Provinces. The greatest duty of water in wheat-growing in

India can be obtained by watering the ground before the crop is sown. This cools the land and will help the wheat to root deeply.

7. *Rice.* As in other crops, oxygen plays a great part in the well-being of the rice plant. In rice, however, we are dealing with a water plant which takes up its air not as free oxygen but as oxygen dissolved in water. In swamp rice, as Dr. Harrison of Madras has shown, the algæ supply the oxygen which, dissolved in water, is carried slowly through the mud in which the rice is growing. In ordinary rice, the highly oxygenated rain water is one of the aeration agencies. As in swamp rice, we must have a little drainage to move this aerated water over the rice roots. We can improve rice cultivation if we can make more use than at present of the surplus rainfall and of the water of rivers like the Ganges. If we confine the rivers of Lower Bengal to their beds by high embankments and prevent them spilling over the country, the result is intense malaria and rural depopulation. Where the rivers spill over, there is little malaria. The method of the aeration of the rice plant probably supplies a part at least of the explanation of these results. Where the rice roots are aerated, the crop does well and there is abundant food for the people. This means increased resisting power to the malarial parasite. Cut off the volume of aeration water by strong river embankments as in the Burdwan District, the yield of rice falls off, there is less food for the people, their resistance to malaria weakens and rural depopulation begins. Aeration of the water of rice land, as Dr. Harrison's interesting work indicates, is probably the chief direction in which many problems relating to the growth and well-being of rice should be studied. Perhaps engineers can tell us whether any practicable means can ever be devised for setting up aeration stations on the rivers of deltaic Bengal and for re-aerating the water. Laboratory and small scale experiments on these lines, however, would be easy and the connection could easily be traced between yield and aeration.

8. *Sugarcane.* The Dutch planters of Java have learnt by long experience, in growing sugarcane on heavy soils, that there exists a close con nection between the yield of sugar and soil-aeration and that the destruction of the porosity of the soil does great harm to the crop. The attention paid to the aeration of the soil in Java is one of the factors on which the development of the sugar industry in that island depends. The circumstances of the island are such that a large supply of rice has to be grown to feed the people. Rice and sugarcane often have to be grown alternately on the same land. It has been found that the only

way to grow sugarcane on such land is to pay great attention to drainage and to aeration. If this is neglected, the cane suffers. One of the best methods of meeting the present competition of Java sugar in India is to improve our soil-aeration just as the Dutch have done. This will increase the yield and quality of the juice and augment the outturn. Nowhere is better aeration for sugarcane so necessary as in Bihar. We shall not derive the full benefit from new seedling canes unless we pay great attention to aeration in the sugar tracts of Northern India.

9. *Opium.* I understand that an opium problem has arisen in India since the discontinuance of the China trade. Indian opium is required, I believe, for medical purposes in England but a difficulty has arisen with regard to the opium produced in Oudh. This opium is too poor in morphine and falls below the standard required by the *British Pharmacopeia.* The problem is to increase the quality. I venture to suggest that this will also be found to be an aeration effect and to result from an insufficient supply of air in the soil. If the opium land is drained on the Pusa system and if *thikra* (at the rate of about 30 to 50 tons per acre) is mixed with the upper six inches of soil, I believe the quality of the Oudh opium will instantly improve.

10. *Forestry.* In the management of Indian forests and in the most ecomomic production of timber like *sal,* great advances are certain to be made when the importance of soil-aeration is understood. This part of the subject is being developed by Mr. Hole, the Imperial Forest Botanist at Dehra Dun, who has been working independently on soil-aeration. In point of time, his work is prior to that done at Pusa and to him must be given the credit for having first recognized what is likely to be a new and important factor in forest growth and management.

11. *Market-garden crops.* I will conclude this lecture by referring to various classes of market-garden crops grown near the large cities and towns in India and in Great Britain. Among English market-garden crops I shall include hop-growing. One of the features of these crops is the intensive cultivation adopted in their production and the concentration of a large capital on a small area. French gardening and green-house work are merely highly developed forms of market-gardening, in which the capital expenditure is still greater. In all these crops, large quantities of organic manures are yearly added to the land. Now one of the great uses of these large quantities of organic manure is to increase the aeration of the soil and to promote rapid root-development. Can we not decrease the annual expense of this manuring by adding a permanent aerator such

as broken tiles or *thikra* ? Experience will decide the point. I think a very good case can be made out for experiments on these lines. Better soil-aeration will probably also prove to be the best cure for the soil sickness which takes place in green-houses in Great Britain and which is now being investigated at Rothamsted.

In this lecture, I have endeavoured to show some of the results which follow from the application of physiological ideas to crop-production. When the importance of soil-aeration is fully realized and the part played by air is understood, the progress made in crop-production will be rapid. I feel sure that when these ideas bear fruit, a new chapter in the development of Agriculture, not only in India but elsewhere, will be opened and the world's production of food and of raw materials will enter on a new phase.

PUSA,
February 7, 1916.

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A Preliminary Chemical Study of the Rices of Bihar and Orissa.

The importance of a chemical study of a valuable food crop like rice is universally acknowledged. In view of this fact the examination of the composition of the rices grown in Bihar and Orissa was undertaken, along with other related questions of interest.

In 1913-14, the most recent year for which figures are available, the area under rice in the Province was 16,233,500 acres out of a total of 25,947,800 acres under crops, constituting 62·6 per cent. of the net area cropped.[1]

Examination of the figures for the last five years shows that in round numbers the area under rice has been between 16 to 18 million acres out of a total of 26 to 28 million acres cultivated, the gross area of the Province being 53 million acres.[2] Rice thus occupies by far the largest area in the Province, the nearest rival being maize which is grown on less than 2 million acres.

Detailed figures for each district (1913-14) are given below :—

District	Area of district (acres)	Area cropped (acres)	Rice area (acres)	Percentage of rice area to area cropped
Patna	1,328,000	876,800	388,600	44·3
Gaya	3,015,680	1,769,600	1,111,700	62·8
Shahabad	2,798,720	1,738,300	676,700	38·9
Saran	1,711,234	1,132,700	428,300	37·8
Champaran	2,259,840	1,399,900	875,500	62·5
Muzaffarpur	1,942,324	1,430,000	952,200	66·6
Darbhanga	2,142,690	1,584,000	955,800	60·3
Monghyr	2,510,080	1,469,500	479,200	32·6
Bhagalpur	2,661,020	1,643,900	1,172,800	71·3
Purnea	3,196,153	1,887,900	1,335,500	70·7
Santhal Parganas	3,466,100	1,840,700	1,065,600	57·9
Cuttack	2,340,307	1,353,900	1,207,000	89·2
Balasore	1,332,621	671,900	587,000	87·4
Angul	1,089,280	244,600	136,200	55·7
Puri	1,599,360	799,700	696.600	87·1
Sambalpur	2,447,360	928,700	699,200	75·3
Hazaribagh	4,473,239	962,800	504,400	52·4
Ranchi	4,544,869	1,588,500	978,100	61·6
Palamau	3,146,396	606,900	340.700	56·1
Manbhum	2,654,080	1,308,800	1,142 900	87·3
Singhbhum	2,507,460	708,700	499,500	70·5

[1] *Agricultural Statistics of Bihar and Orissa,* 1913-14.

[2] *Agricultural Statistics of India,* 1912-13, vol. i.

Details of the rice area in the Native States, which occupy a total area of 18,331,720 acres, are not available.

It will be noted that the rice area is more than half the area under crops in all the districts except Patna, Shahabad, Saran and Monghyr (see map). These are riverain tracts wh re a certain amount of sand has been mixed with the clay and are thus pre-eminently the wheat-growing tracts of Bihar.[1] But even in these districts rice occupies more than 30 per cent. of the cropped area. In Santhal Parganas, Palamau, Hazaribagh and Angul it is between 50 and 60 per cent., while in Ranchi, Gaya, Champaran, Muzaffarpur and Darbhanga it ranges between 60 and 70 per cent. Then come Sambalpur, Singhbhum, Bhagalpur and Purneah where it is from 70 to 80 per cent. The most important rice-producing districts are, however, the districts of Puri, Cuttack, Balasore and Manbhum. The three deltaic Orissa districts present conditions which are extremely favourable to the growth of rice. In Manbhum, the surface of the country being of an extremely undulating nature, the cultivators have taken care to convert the slopes and hollows, wherever practicable, into terraces of different levels. By means of protective embankments, the rainfall is retained on each particular terrace or field. Such a system of cultivation is suitable mainly for rice, and rice is the main crop of this district.[2]

There are innumerable varieties of rice. But they all fall under one or other of the three main classes, *viz.*, (1) the *áus*, *bhádoi* or early rice crop, (2) the *áman*, *aghání* or winter rice crop and (3) the *boro* or spring rice crop. Each class comprises a large number of varieties differing from each other in minor characteristics of shape, size, colour, flavour, culinary value etc. The coarse early rice is mainly eaten by the poorer people while the richer classes use the finer late rices. It is interesting to note that in Sanskrit literature mention is made of two classes of rice, *viz.*, *sáli* (which corresponds to *áman*) and *bríhi* (*áus*).[3] *Shasthika* (*sáthi* or sixty day rice) is sometimes mentioned as a distinct class. The writers describe the distinctive property of *Shasthika* to consist in " attaining ripeness while the seed is still in the womb " referring to the peculiarity of the *sáthi* rice of ripening while the panicle has not yet emerged from the sheath.

Reference may be made here to records of previous analyses of rice.

Church analysed a large number of " cleaned " rice and recorded the average composition in his book on food grains.[4]

Balland published in 1895 a paper on the composition of rice imported into France.[5]

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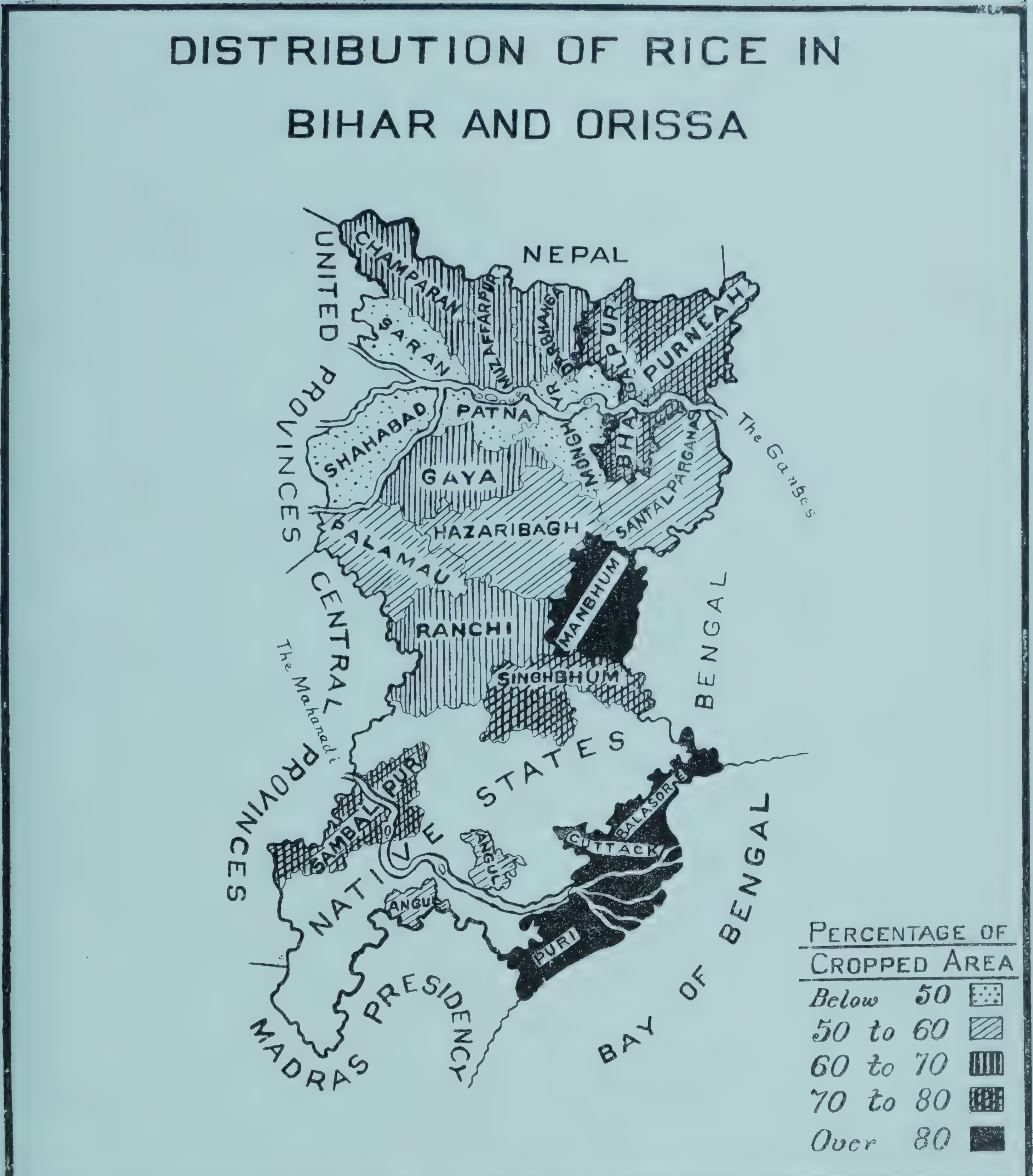
[1] Howard and Howard, *Wheat in India*, p. 17.
[2] *Bengal Dist. Gazetteer*, vol. xxviii, p. 113, (1911).
[3] Sen, B. L., *Ayurveda-vijnána*, vol. iii, p. 239
[4] *Food grains of India*, ed. 1886, p. 73.
[5] *Compt. rend.*, 1895, cxxi, 561 ; *J. C. S.*, 1896, as. ii, 212.


DISTRIBUTION OF RICE IN BIHAR AND ORISSA
NEPAL
UNITED PROVINCES
CHAMPARAN
SARAN
MUZAFFARPUR
DARBHANGA
BHAGALPUR
PURNEAH
SHAHABAD
PATNA
GAYA
MONGHYR
SANTAL PARGANAS
The Ganges
PALAMAU
HAZARIBAGH
MANBHUM
RANCHI
SINGHBHUM
CENTRAL PROVINCES
The Mahanadi
BENGAL
NATIVE STATES
SAMBALPUR
ANGUL
BALASORE
CUTTACK
PURI
MADRAS PRESIDENCY
BAY OF BENGAL
PERCENTAGE OF CROPPED AREA
Below 50
50 to 60
60 to 70
70 to 80
Over 80

In 1895 Wiley published the records of his analyses of the samples of rice sent as exhibits to the World's Columbia Exposition, Chicago.[1] He also quoted the analyses made by Jenkins and Winton and by König.

Leather's analysis of four samples of coarse and four of fine rice was published in 1903.[2]

Hooper analysed a large number of Indian rices.[3] The figures for the Bihar and the Orissa rices are quoted below in their proper place.

In 1911 Aron and Hocson, in connection with their study of rice as a food stuff, analysed a series of milled and unmilled rice of various grades.[4] They found the percentage of phosphoric acid to vary between the following limits :—

Unmilled rice	0·7 to 0·8
Undermilled rice	0·4 to 0·6
Overmilled rice	0·15 to 0·4

In 1911 Hooper published a paper on "Phosphorus in Indian Foodstuffs."[5] He found that husked rice contained, on an average, 1·6 per cent. ash which varied in the different samples from 1·3 to 2·1 per cent. The phosphoric acid varied from 0·58 to 0·80 per cent., the average figure being 0·65. Samples of milled rice collected in Calcutta had, on an average, 0·88 per cent. ash, the variations being from 0·63 to 1·70 per cent. The average percentage of phosphoric acid was 0·36, the minimum and maximum figures being 0·22 and 0·50.

Warth and Darabsett published in 1913 their paper on "The Chemical Composition of Paddy Mill Products."[6] They found the following changes to be brought about by the milling process :—

	% Nitrogen	% Phosphoric acid	% Potash
White Ngasein, husked . .	1·13	0·71	..
White Ngasein, polished . .	1·07	0·25	..
Red Ngasein, husked . . .	1·11	0·67	..
Red Ngasein, polished . .	0·99	0·23	..
Byat, husked	1·09	0·69	0·30
Byat, polished	0·98	0·24	0·08

The Japanese rices have been studied by many authors. Kellner in 1889 studied the effect of whitening rice.[7] He found these rices poor in mineral ingredients, the average amounts in the raw and in the

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[1] *U. S. A., Dep. Agri., Bur. Chem., Bul.* 45.
[2] *Agri. Ledger*, 1903, No. 7.
[3] *Agri. Ledger*, 1908-9, No. 5.
[4] *Biochem, Zeits.*, 1911, xxxii, 189 ; *J. C. S.*, 1911, abs., ii, 625.
[5] *Jour. As. Soc. Bengal*, 1911, vii, p. 313 ; *J. S. C. I.*, 1912, xxxi, 88.
[6] *Burma Dept. Agri., Bul.* 10 of 1913.
[7] *Bul. Imp. Coll. Agri., Tokyo*, vol. i, no. 5.

whitened grains being 1·15 and 0·5 per cent. respectively. The percentage of phosphoric acid and potash in the hulled grain was 0·59 and 0·26 respectively.

In 1892 Kellner and Nagakoa showed that the price of rice has no relation to its composition.[1] Sawamura subsequently studied the relation between quality and composition of rice and obtained nearly the same result.[2] He also concluded that inferior rice is likely to be rich in fatty matters and ash, and certainly in extractive matters.

Takahashi and Sato in 1913 studied the chemical composition of polished rice used for brewing Saké.[3]

In America, Ross[4] and Browne[5] have studied the chemical composition and feeding value of rice products.

Much work has also been done by Krauss, Kelley and Miss Thompson at the Hawaii Agricultural Station.[6]

These records are presented in a tabular form below.

It should be noted here that the word " husked " rice has been used to indicate rice simply husked, *i.e.*, rice " in the bran." " Polished " rice means rice which has had much of the " skin " and the germ removed in the course of the polishing operation. Paddy refers to the unhusked grains.

TABLE I.

Composition of husked rice as recorded by previous workers.

Variety	Weight in grams of one thousand grains	GRAMS PER 100 GRAMS AIR-DRY RICE						Authority
		Moisture	Ether extract	Albuminoids	Soluble carbo-hydrates	Woody fibre	Ash	
World's Fair, average	24·66	11·88	1·96	8·02	76·05	0·93	1·15	Wiley.
Average . . .	..	12·58	1·88	6·73	76·46	1·53	0·82	Kõnig.
Burma, white Ngasein	..	12·77	2·06	..	..	0·60	1·33	Warth and Darabsett.
„ red Ngasein .	..	13·97	2·21	6·94	74·76	0·72	1·40	Do.
„ Byat . .	..	12·31	2·44	6·88	76·05	0·27	1·90	Do.
Japan, Mino (superior).	..	(13·42)	3·14*	9·40*	84·55*	1·39*	1·52*	Kellner.
Japan, Echiu (medium)	..	(13·65)	2·43*	7·98*	86·72*	1·83*	1·04*	Do.
Louisiana, average white rice	..	..	2·50	8·14	72·01	..	..	Browne.
Hawaii . . .	..	13·79	2·13	7·14	72·87	2·74	1·33	Krauss.

* These figures refer to percentages in the dry matter of the rice.

1 *Bul. Imp., Coll. Agri., Tokyo*, vol. i, no. 12, quoted by Takahashi and Sato (*poste*).
2 *Jour. Agri. Soc.*, No. 51, quoted by Takahashi and Sato.
3 *Jour. Coll. Agri., Tokyo*, vol. v, no. 2.
4 *Bull. Agri. Exp. Sta., Louisiana*, No. 24, quoted by Browne (*poste*).
5 *Bul. Agri. Exp. Sta., Louisiana*, second series, No. 77.
6 *Hawaii Agri. Exp. Sta., Reports* for 1907. *et seq.*

TABLE II.

Composition of polished rice as recorded by previous workers.

Variety	Weight in grams of one thousand grams	GRAMS PER 100 GRAMS AIR-DRY RICE						Authority
		Moisture	Ether extract	Albuminoids	Soluble carbo-hydrates	Woody fibre	Ash	
Indian . . .	..	12·80	0·60	7·30	78·30	0·40	0·60	Church.
Indian, maximum .	..	14·00	0·45	7·01	80·27	0·31	0·44	Balland.
Indian, minimum .	..	11·70	0·15	6·14	78·60	0·21	0·34	Do.
World's Fair, average	21·32	12·34	0·26	7·18	79·36	0·40	0·46	Wiley.
Average . . .	..	12·52	0·84	7·52	78·00	0·48	0·64	König.
Average . . .	..	12·40	0·40	7·40	79·20	0·20	0·40	Jenkins and Winton.
Bhagalpur, Lali bagra	16·9	12·35	0·36	8·27	77·16	0·76	1·10	Hooper.
Bhagalpur, Kataribhog.	14·9	12·40	0·20	7·31	78·96	0·38	0·75	Do.
Gaya, Chokachanti .	19·3	12·95	0·18	6·92	78·93	0·27	0·75	Do.
Cuttack, maximum .	18·2	11·65	0·48	7·56	82·73	0·50	1·30	Do.
Cuttack, minimum .	7·0	9·40	0·20	5·44	79·47	0·18	0·60	Do.
Cuttack, average .	12·3	10·92	0·31	6·58	80·81	0·35	1·03	Do.
Burma, White Ngasein.	..	11·48	0·54	6·94	80·39	0·16	0·49	Warth and Darabsett.
Do. Red Ngasein.	..	14·63	0·36	6·22	77·84	0·43	0·52	Do.
Do. Byat . .	..	12·50	0·49	6·25	80·15	0·15	0·46	Do.
Japan, Mino (superior).	..	(15·21)	1·46*	8·25*	89·02*	0·56*	0·71*	Kellner.
Do. Echiu (medium).	..	(15·27)	0·95*	6·69*	91·35*	0·46*	0·65*	Do.
Louisiana . .	..	12·85	0·38	7·52	78·05	0·47	0·73	Ross.
Hawaii . . .	..	14·10	0·46	6·78	76·86	1·32	0·48	Krauss.

* These figures refer to percentages in the dry matter of the rice.

Composition of the Rices.

It was thought desirable to confine the work to samples of rice in the Government farms, where they are grown under definite cultural conditions. The rices were, however, not all pure line cultures. Of the samples received, three came from Bankipore, one from Bettiah, three from Cuttack, six from Dumraon and five from Sabour. Out of these eighteen samples, six were *aus* and the rest *aman*. They did not include any *boro* rice.

The samples of paddy were unhusked by gently rubbing them against two smooth planks of wood. The paddy as well as the rice obtained

by this process were weighed and the yield of the latter was deduced therefrom. The sample was then submitted to analysis. The volumes occupied by 100 grams of the grain were then noted for working out their weight per litre.

Hundred grains of paddy were weighed, as also the rice obtained by carefully husking them by hand. From these figures the weights of one thousand grains were calculated. The percentage of the yield of rice from this small lot of one hundred grains is evidently not a reliable average figure and the figure obtained by the previous operation from the larger samples has been recorded in the table.

The records of the analyses of eighteen samples are enumerated below.

[*For Table see next page.*

TABLE III.

Composition of Bihar rices (husked).

Farm	Variety	Weight in grams of 1 litre paddy	Rice yielded per cent.	WEIGHT IN GRAMS OF 1,000 GRAINS		GRAMS PER 100 GRAMS AIR-DRY RICE									
				Paddy	Rice	Moisture	Ether extract	Albuminoids	Soluble carbo-hydrates	Woody fibre	Ash	NITROGEN		Phosphoric acid	Postash
												Albuminoid	Total		
Cuttack	C. P. Fine Aus	529	66·8	12·63	9·50	12·31	2·23	7·44	75·59	1·02	1·41	1·18	1·19	0·68	0·38
Do.	Benibhog Aus	610	73·4	14·29	10·88	12·20	2·66	6·31	76·58	0·68	1·57	1·00	1·01	0·68	0·42
Do.	Tuishiphul Aus	581	75·2	23·09	18·19	12·36	2·48	7·82	74·85	0·97	1·52	1·23	1·25	0·72	0·39
Sabour	C. P. Aus	602	72·3	11·63	8·87	12·15	2·11	7·69	75·06	0·87	2·12	1·23	1·23	0·85	0·50
Do.	Kaitki	602	73·1	20·04	15·38	12·32	2·19	7·19	76·12	0·67	1·51	1·14	1·15	0·63	0·35
Do.	Kajarghore	571	78·5	24·21	19·01	12·12	2·39	7·69	75·75	0·72	1·33	1·18	1·23	0·68	0·39
Do.	Hemcha	599	70·7	22·96	17·96	12·45	2·44	8·64	74·44	0·57	1·46	1·36	1·38	0·65	0·30
Do.	Kalamdan	575	71·4	24·67	19·27	12·58	2·30	7·32	75·94	0·53	1·33	1·13	1·17	0·65	0·29
Bankipore	C. P. Aus	571	75·8	12·48	9·64	12·28	2·19	7·56	75·28	0·95	1·74	1·20	1·21	0·81	0·47
Do.	Kartika	588	70·2	25·91	19·43	12·28	2·42	7·56	75·23	0·84	1·67	1·19	1·21	0·68	0·27
Do.	Sathi Aus	649	78·7	22·71	18·21	12·32	1·98	7·75	75·84	0·84	1·27	1·23	1·24	0·58	0·28
Bettiah	Kaitki	575	66·4	..	..	12·53	2·40	7·26	75·76	0·66	1·39	1·15	1·16	0·58	0·29
Dumraon	Dadkhani	562	70·6	13·98	10·97	11·34	2·23	7·44	76·43	0·65	1·91	1·18	1·19	0·76	0·38
Do.	Kalamdan	565	71·8	25·23	19·51	11·14	2·40	6·06	78·36	0·50	1·54	0·97	0·97	0·66	0·35
Do.	Moharajwa	581	73·3	24·98	19·36	10·82	2·51	7·00	77·42	0·71	1·54	1·12	1·12	0·74	0·39
Do.	Badshabhog	575	71·9	10·62	8·35	11·44	2·59	8·63	74·60	0·90	1·84	1·37	1·38	0·83	0·36
Do.	Bansphul	565	69·0	18·87	14·72	11·31	2·45	7·13	76·66	0·80	1·65	1·13	1·14	0·65	0·32
Do.	Srikole	602	74·2	11·86	9·07	11·20	2·54	8·00	75·81	0·71	1·74	1·28	1·28	0·79	0·33
	AVERAGE	583	72·4	..	..	11·95	2·36	7·48	75·86	0·76	1·59	1·20	1·21	0·70	0·36

The average volume weight of the unhusked paddies was 583 grams per litre, the highest being 649 (*Sathi*, Bankipore) and the lowest, 529 (*C. P. Aus*, Cuttack).

The yield of rice from these paddies was, on an average, 72·4 per cent. by weight. The highest amounts were 78·7 and 78·5 per cent. from *Sathi*, Bankipore and *Kajarghore*, Sabour, respectively. The lowest yield was from *Kaitki*, Bettiah, being only 66·4 per cent.

It is not surprising to find some differences in the moisture content of the rices—a feature which is due to differences in the atmospheric conditions at the time of the preparation of the samples. A knowledge of the amount of moisture is of importance to the consumer, since, other things being equal, the drier the rice is, the larger the amount of nutritive substance does he get for his money. But of course for this purpose the moisture content should be determined at the very time of buying the rice.

Comparing the average values with those obtained by previous workers it is seen that the composition of rice does not vary much. The amount of moisture is practically identical with that found by Wiley and very near the amounts found by the others. The Bihar rices seem to be richer in oil, or ether extract, than those examined by Wiley and König. As regards the albuminoids, it may be noted that the figure recorded by König is open to some doubt as it indicates the polished rices being *richer* in albuminoids than the unpolished—a statement which is inconsistent with the results obtained in the course of all the later investigations. The Bihar and the Burma rices seem to be richer in mineral constituents than the Japan rices examined by Kellner.

Although the composition of air-dry rice has been given above, mainly to facilitate ready comparison with figures obtained by previous workers, it seems better, in order to get strictly comparative results, to calculate the figures on the basis of dry matter in the samples. A table incorporating such figures is accordingly given below.

[*For Table see next page.*

TABLE IV.

Composition of Bihar rices (husked).

Farm	Variety	GRAMS PER 100 GRAMS DRY MATTER								
		Ether extract	Albuminoids	Soluble carbo-hydrates	Woody fibre	Ash	NITROGEN		Phosphoric acid	Potash
							Albuminoid	Total		
Cuttack	C. P. Fine Aus	2·54	8·50	86·20	1·16	1·60	1·35	1·36	0·78	0·43
Do.	Benibhog Aus	3·03	7·19	87·26	0·77	1·75	1·14	1·15	0·77	0·48
Do.	Tulshiphul Aus	2·83	8·94	85·39	1·11	1·73	1·40	1·43	0·83	0·44
Sabour	C. P. Aus	2·41	8·75	85·44	0·99	2·41	1·39	1·40	0·96	0·57
Do.	Kaitki	2·49	8·19	86·84	0·76	1·72	1·30	1·31	0·72	0·40
Do.	Kajarghore	2·72	8·76	85·88	0·82	1·82	1·34	1·40	0·77	0·45
Do.	Hemcha	2·78	9·88	85·01	0·66	1·67	1·55	1·58	0·74	0·34
Do.	Kalamdan	2·63	8·38	86·87	0·60	1·52	1·29	1·34	0·75	0·33
Bankipore	C. P. Aus	2·50	8·62	85·79	1·09	2·00	1·37	1·38	0·92	0·53
Do.	Kartika	2·76	8·62	85·76	0·96	1·90	1·36	1·38	0·77	0·31
Do.	Sathi Aus	2·26	8·81	86·51	0·97	1·45	1·40	1·41	0·67	0·32
Bettiah	Kaitki	2·74	8·24	86·68	0·75	1·59	1·31	1·32	0·66	0·33
Dumraon	Dadkhani	2·52	8·37	86·22	0·73	2·16	1·33	1·34	0·86	0·43
Do.	Kalamdan	2·70	7·00	88·01	0·56	1·73	1·12	1·12	0·74	0·39
Do.	Moharajwa	2·81	7·88	86·78	0·80	1·73	1·26	1·26	0·83	0·43
Do.	Badshabhog	2·91	9·75	84·24	1·02	2·08	1·55	1·56	0·94	0·41
Do.	Bansphul	2·77	8·07	86·40	0·90	1·86	1·27	1·29	0·73	0·36
Do.	Srikole	2·86	9·00	85·38	0·80	1·96	1·44	1·44	0·89	0·38
	AVERAGE	2·68	8·50	86·14	0·86	1·82	1·36	1·38	0·80	0·41

Ether extract or Oil. The amount of oil varies between very small limits, the average amount being 2·68 per cent. The sample richest in oil was *Benibhog*, Cuttack (3·03 per cent.), the poorest being *Sathi*, Bankipore (2·26 per cent.).

It may seem at first sight that the oil content is influenced more by the variety than the conditions of soil and climate. Before, however, any definite conclusion can be laid down the number of samples examined should be greater. Moreover the "varieties" from the different localities should be uniform.

Albuminoids. These figures are obtained by multiplying the total nitrogen by the usual analytical factor 6·25. As the previous workers have used the total nitrogen figure, this has been taken in account, and not the albuminoid nitrogen. The difference, moreover, between the total and the albuminoid nitrogen is small, the average being 0·02 per cent. which corresponds to a difference of 0·13 per cent. of albuminoids.

The proteins of rice have been specially studied by Rosenbeim and Kajiura,[1] Suzuki, Yoshimura and Fuji,[2] and later by Kajiura,[3] and Takahashi and Sato.[4]

The percentage of albuminoids ranges from 7·00 (*Kalamdan*, Dumraon) to 9·88 (*Hemcha*, Sabour), the average being 8·50. These are the most important constituents but the comparatively large differences in nutritive value as evidenced by these figures do not seem to bear any relation to the accepted culinary properties of the samples.

It is interesting to note that the three samples of *C. P. Aus* contain practically the same amount of albuminoids.

Soluble carbohydrates. These figures are obtained by difference. The nitrogen-free extractive substances in feeding stuffs have been lately investigated by König.[5]

The sample richest in soluble carbohydrates is *Kalamdan* from Dumraon (88·01 per cent.), the poorest being *Badshabhog* from the same locality (84·24 per cent.) The average amount is 86·14 per cent.

Crude fibre. The results are here quite uniform, and the differences are such as might almost be accounted for by the unavoidable error of experiment. The average percentage is 0·86, the highest being 1·16 in *C. P. fine Aus*, Cuttack, and the lowest, 0·60 in *Kalamdan*, Sabour.

Ash. Here also the results are uniform, the average content of mineral matter being 1·82 per cent. The richest sample was *C. P. Aus*, Sabour (2·41 per cent.) and the poorest, *Sathi*, Bankipore (1·45 per cent.).

[1] *Proc. Physiol. Soc.*, 1908, liv. ; *J. C. S.*, 1908, abs., ii, 317.
[2] *J. Coll. Ag., Tokyo*, 1909, i, 77 ; *J. C. S.*, 1909, abs., ii, 927.
[3] *Biochem. J.*, 1912, vi, 171 ; *J. C. S.*, 1912, abs., ii, 291.
[4] *Loc. cit.*
[5] *Zeits. Untersuch. Nahr. u. Genussmtl.*, 1913, xxvi, 273 ; *Chem. Abs., Amer. Chem. Soc.*, 1914, viii, p. 379.

These analyses allow an interesting deduction. Since the amounts of oil, fibre and ash vary between very narrow limits it follows that the sum of these constituents will be more or less constant. The sum total of the remaining constituents of albuminoids and soluble carbohydrates is thus also constant. On examination it will be found that the sum of the percentage figures for albuminoids and soluble carbohydrates, in all instances except three, falls between 94 and 95. In these three latter cases the figures are 93·9 (*Hemcha*, Sabour) and 95·3 (*Kalamdan*, Sabour and *Sathi*, Bankipore). But the deviation is so small that the general observation may be said to hold good in these instances also. It will thus be seen that when the amount of albuminoids is high the carbohydrate content is low and *vice versâ*.

Nitrogen. The average amounts of albuminoid and total nitrogen are 1·36 and 1·38 per cent. The richest sample is *Hemcha*, Sabour (1·55 and 1·58 per cent. respectively), the poorest being *Kalamdan*, Dumraon (1·12 per cent.). Suzuki, Yoshimura and Fuji found that the dry matter of rice freed from husks contained 1·20 per cent. total nitrogen and 1·17 per cent. of albuminoid nitrogen.

Phosphoric acid. The average percentage of this constituent is 0·80; the maximum being 0·96 in *C. P. Aus*, Sabour and the minimum, 0·66 in *Kaitki*, Bettiah.

Potash. The average potash content is 0·41 per cent., the highest, 0·57 per cent. in *C. P. Aus*, Sabour and the lowest, 0·31 in *Kartika*, Bankipore.

It is to be noted that the amount of phosphoric acid is always very slightly less than half of the total mineral matter present. Potash is, again, very nearly half of the amount of phosphoric acid present. Wolff gives the composition of rice ash as 53·68 per cent. phosphoric acid and 21·73 per cent. potash.[1]

The effect of polishing.

The analyses quoted above are of rices which had been carefully unhusked by gentle rubbing. The rice which is used by the villagers, however, is unhusked in a *dhenki* and is partly polished. An attempt was made to see how far the latter process affected the composition.

Samples of the paddies were therefore unhusked in an *okhri*, the indigenous wooden mortar and pestle, the operation being continued till much of the coloured "skin" was removed. Analyses of these are recorded below.

[1] *Aschen Analysen*, p. 154.

TABLE V.

Composition of Bihar rices (polished).

Farm	Variety	Per cent. polished rice yielded by unhusked paddy	Weight in grams of 1 litre polished rice	GRAMS PER 100 GRAMS AIR-DRY RICE									
				Moisture	Ether exract	Albuminoids	Soluble carbohydrates	Woody fibre	Ash	NITROGEN		Phosphoric acid	Potash
										Albuminoid	Total		
Cuttack	C. P. Fine Aus	61·2	807	9·91	1·65	7·50	79·86	0·24	0·84	1·18	1·20	0·46	0·24
Do.	Benibhog Aus	66·2	855	9·45	1·43	6·12	81·71	0·33	0·96	0·96	0·98	0·42	0·40
Do.	Tulshiphul Aus	66·4	820	8·81	1·25	7·88	80·59	0·55	0·92	1·22	1·26	0·48	0·28
Sabour	C. P. Aus	63·0	848	10·69	1·20	7·50	78·99	0·28	1·34	1·20	1·20	0·39	0·32
Do.	Kaitki	66·0	769	11·32	0·12	7·26	79·33	0·28	0·69	1·14	1·16	0·24	0·19
Do.	Kajarghore	52·5	833	11·28	0·55	6·94	80·55	0·10	0·58	1·09	1·11	0·27	0·19
Do.	Hemcha	56·8	820	10·76	0·60	8·25	80·26	0·13	0·60	1·31	1·32	0·29	0·19
Do.	Kalamdan	54·4	820	10·94	0·47	6·81	81·11	0·07	0·60	1·08	1·09	0·27	0·17
Bankipore	C. P. Aus	62·3	800	11·60	1·14	7·39	78·91	0·05	0·91	1·16	1·18	0·41	0·19
Do.	Kartika	57·4	813	11·82	0·90	7·44	78·98	0·15	0·71	1·18	1·19	0·32	0·14
Do.	Sathi Aus	63·9	826	11·32	1·15	7·69	79·03	0·20	0·61	1·22	1·23	0·28	0·16
Bettiah	Kaitki	61·1	800	11·54	1·10	7·07	79·55	0·15	0·59	1·11	1·13	0·26	0·17
Dumraon	Dadkhani	61·0	800	11·68	0·84	7·13	79·26	0·15	0·94	1·13	1·14	0·48	0·24
Do.	Kalamdan	59·2	813	11·83	0·85	5·69	80·42	0·35	0·86	0·90	0·91	0·39	0·25
Do.	Moharajwa	61·7	800	11·65	0·84	6·50	79·86	0·30	0·85	1·04	1·04	0·41	0·22
Do.	Badshabhog	67·0	807	12·08	0·99	8·63	77·37	0·10	0·83	1·38	1·38	0·44	0·26
Do.	Bansphul	57·7	813	9·40	0·60	6·69	82·62	0·10	0·59	1·05	1·07	0·25	0·13
Do.	Srikole	59·4	826	9·93	0·68	7·69	80·89	0·03	0·78	1·23	1·23	0·36	0·21
	AVERAGE	60·96	815	10·89	0·88	7·25	79·99	0·20	0·79	1·14	1·16	0·36	0·22

A comparison of the yields of the unpolished and the polished rice from paddy shows that the amount of "bran" removed during the latter operation varies between relatively wide limits.

The composition of the polished rice is mostly similar to that recorded by previous workers. The oil content, however, is higher in the Bihar samples. Whether this is due to the inherent richness in oil of Bihar paddy or to the fact that the samples used by the previous workers were more perfectly "milled" cannot be definitely stated. Perhaps both these factors have an influence. It is to be noted that the Burma rice, which was originally nearly as rich in oil, contained, after polishing, less oil than the Bihar rice. This was presumably due to the more perfect removal of the "skin" in the power mill.

The composition of the polished rice as computed with respect to the dry matter is given in the following table :

[*For Table see next page.*

TABLE VI.

Composition of Bihar rices (polished.)

Farm	Variety	GRAMS PER 100 GRAMS DRY MATTER								
		Ether extract	Albuminoids	Soluble carbo-hydrates	Woody fibre	Ash	NITROGEN		Phosphoric acid	Potash
							Albuminoid	Total.		
Cuttack	C. P. Fine Aus	1·83	8·38	88·60	0·27	0·92	1·31	1·34	0·51	0·26
Do.	Benibhog Aus	1·57	6·76	90·24	0·37	1·06	1·06	1·08	0·47	0·44
Do.	Tulshiphul Aus	1·38	8·69	88·31	0·61	1·01	1·34	1·39	0·53	0·31
Sabour	C. P. Aus	1·34	8·38	88·46	0·31	1·51	1·34	1·34	0·44	0·36
Do	Kaitki	1·27	8·19	89·44	0·32	0·78	1·29	1·31	0·27	0·21
Do.	Kajarghore	0·62	7·88	90·73	0·11	0·66	1·23	1·26	0·31	0·22
Do.	Hemcha	0·67	9·25	89·26	0·14	0·68	1·47	1·48	0·33	0·31
Do.	Kalamdan	0·53	7·69	91·02	0·08	0·68	1·21	1·23	0·31	0·19
Bankipore	C. P. Aus	1 30	8·38	89·23	0·06	1·03	1·31	1·34	0·46	0·21
Do.	Kartika	1·01	8·44	89·58	0·17	0·80	1·34	1·35	0·36	0·16
Do.	Sathi Aus	1·30	8·69	89·11	0·21	0·69	1·38	1·39	0·32	0·18
Bettiah	Kaitki	1·24	8·00	89·92	0·17	0·67	1·25	1·28	0·29	0·19
Dumraon	Dadkhani	0·95	8·25	89·57	0·17	1·06	1·28	1·32	0·54	0·27
Do.	Kalamdan	0·96	6·51	91·17	0·39	0·97	1·02	1·04	0·44	0·29
Do.	Moharajwa	0·96	7·38	90·36	0·34	0·96	1·18	1·18	0·46	0·25
Do.	Badshabhog	1·13	9·76	88·05	0·11	0·95	1·56	1·56	0·50	0·30
Do.	Bansphul	0·66	7·44	91·14	0·11	0·65	1·16	1·19	0·28	0·15
Do.	Srikole	0·75	8·51	89·85	0·03	0·86	1·36	1·36	0·40	0·24
	AVERAGE	1·09	8·14	89·66	0·22	0·89	1·28	1·30	0·40	0·32

The figures quoted above may now be compared with those given for the composition of the dry matter of the husked rice (unpolished).

The composition of polished rice is dependent somewhat on that of the original unhusked rice. But although the amount of substance removed as bran is not very much, the grain suffers a material alteration in composition. The polished rice becomes poorer in all constituents except soluble carbohydrates which increase a little. The amount of oil decreases to less than half ; the albuminoids suffer only a slight diminution ; the fibre is reduced to about one-fourth of the original quantity and the amount of mineral constituents falls to a half. The outer layers and the embryo which are removed during the polishing operation are thus seen to be richer than the inner material in all these constituents. But the concentrations of fibre and oil in the bran are relatively higher than that of the mineral constituents. The distribution of the albuminoids is more uniform than that of any of the above.

As the albuminoids are calculated from the total nitrogen, what has been noted about the albuminoids also holds good about this constituent.

It has been noted already that in the unpolished grain the quantity of phosphoric acid is just less than half of the ash. In the polished rice also, the phosphoric acid is slightly less than half of the amount of ash. The potash content, however, which in the unpolished rice is about half of that of the phosphoric acid now rises to about three-fourths of the amount of phosphoric acid.

It thus amounts to this that, although both phosphoric acid and potash are more concentrated in the " bran " than in the rest of the seed, the distribution of the potash is more uniform than that of the phosphoric acid.

As regards the material lost during the operation of polishing, this consists of the plant embryo and some of the outer layers of the grain. The germ, being freely exposed and not embedded in the grain, is easily rubbed off, the little nick at one end of the polished grain marking the place where it was located. A microscopic examination[1] of sections of rice grains shows that in the samples unhusked in the *okhri* most of the outer coating and much of the aleurone layers are absent. In the samples of more perfectly polished rice obtained from Calcutta, of which analyses are given in the appendix, even some of the deeper lying cells, containing starch, are removed.

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[1] Cross-section of a rice grain is illustrated in Winton's *Microscopy of Vegetable Foods*, p. 106.

Rice as an article of diet.

It might be supposed that the estimation in which any variety of rice is held among the consumers, as evidenced by its market price, would be mainly determined by its nutritive value and its palatibility. The latter term includes culinary properties, such as flavour, consistence, appearance, taste, etc., which cannot be definitely described. These are very vague factors, difficult to observe accurately, and their appraisement is much influenced by the personal equation, depending on the habits and idiosyncrasy of the observer. No attempt has, therefore, been made to determine them in this work.

As regards the nutritive value of rice, as revealed by analysis, there is no doubt that, other things being equal, the variety of rice which contains larger amounts of albuminoids is more valuable, in as much as albuminoids, which are the flesh-formers, are a more expensive form of food than starch. The relative nutritive value of a sample of rice can thus be assumed to depend on its albuminoid content. No doubt the nutrition which a man derives from any article of diet does not wholly depend on the absolute amount of the essential constituents, but rather on that part of the latter which he can digest. But as this is an unknown factor, so far as the rice albuminoids are concerned, and as it depends somewhat on the personal habits of the consumer, the above assumption as to the relation between the nutritive value and the composition of rice can be safely taken to hold good. It would be noticed, however, that just as in the case of wheat,[1] no accurate relation can be found between the chemical composition and the value of a rice from the consumer's point of view.

In a well-balanced ration, the relations between the albuminoids, the oil and the soluble carbohydrates should vary within certain definite limits. Rice, however, in common with other cereals, contains an excessive proportion of starch and is thus not suitable for use as the sole article of diet by any one.

This holds not only from the point of view of the organic constituents but also of the mineral ones, which are the bone-formers. Rice is quite poor in this respect also. Ingle [2] has urged the importance of giving due consideration to the amount and composition of the ash of foods, for the supply of material for the proper development of bone, and of the mineral constituents necessary for vital processes factors which have as much influence on the well-being of animals as proteids, carbohydrates and fats in appropriate quantities.

Where a variety of food stuffs is used, the probability of much injury being done by ignoring these aspects of the question is not very great.

[1] Howard and Howard, *Wheat in India*, p. 146.

[2] *Jour. Agri. Sci.*, vol. iii, p. 22.

Happily the use of rice is nearly always supplemented by the addition of other substances of vegetable and animal origin which often supply the deficient elements.

An interesting characteristic of rice protein may be mentioned here. Osborne, van Slyke, Leavenworth and Vinograd have recently shown that in its general amino acid make-up, the protein of rice more nearly resembles the majority of the proteins of animal tissues than do the proteins of maize and wheat[1]. This may explain the fact that rice, in spite of its low protein content, furnishes food for more human beings than any other cereal.

The alteration in composition which rice undergoes during the process of polishing is of great significance from the medical point of view. It was in 1897 that Eykman found that the addition of rice bran to whitened rice prevents the outbreak of beri-beri. Since then a large amount of work has been done on the subject. Some workers believe that beri-beri is due to specific germs. Others think that it is caused by the bacterial fermentation of the large amounts of carbohydrates eaten in unbalanced diet. But the concensus of opinion is that beri-beri is one of the " deficiency diseases " like, *e.g.*, scurvy or rickets. Most of the food articles in their raw state contain the curative substances. These are, however, at times lost, or considerably reduced, during the processes of " finishing " and preparation which the fastidious taste of the modern consumer prescribes. An interesting account of the work on the subject of beri-beri in its chemical aspect and a full bibliography will be found in the book on " Vitamines " by C. Funk[2]. Reduction in the content of phosphoric acid is now generally accepted as an index of the beri-beri-producing-power of a sample of rice. Rice having 0·47 per cent. phosphoric acid has been found to be a healthy food for fowls while rice containing 0·28 per cent. brought about polyneuritis in a few weeks. Judged by this standard, although all samples of unhusked rice used during this investigation were good, many samples of the " polished " rice were unfit for consumption as a sole article of diet. It must be remembered, however, that rice is almost universally supplemented by some other food stuffs, the mixed diet often to a great extent nullifying much of the apprehended injurious effects.

It is to be noted that the polishing which these samples received is not so thorough as the samples polished in mills. For the sake of comparison a table of analysis of polished rice obtained from Calcutta is given in the appendix.

As regards the mode of the preparation of rice for the table it is too well known to require any description. Objection has been raised by Kellner[3] to the preliminary process of washing because it leads to loss

[1] *Journ. Biol. Chem.*, 1915, xxii 259 ; E.S.R., 1915, xxxiii, 867

[2] *Die Vitamine*, pp. 27-70.

[3] *Loc. cit.*

of some nutrients. In these parts of the country rice is washed till the washings are no longer "milky," *i.e.*, till nearly all the small particles of bran and broken rice sticking to the grains are removed. Although these particles no doubt consist of a substance relatively very rich in oil and albuminoids, their presence judged by their palatability and digestibility is not welcome. They would moreover introduce a certain element of stickiness in the boiled rice—a condition of things which is not liked by the consumer. Further, as Cribb and Richards have proved, deleterious substances like french chalk, etc., are often used in the "polishing" of rices, and these stick to the polished grain.[1] Washing of the rice is a very simple but efficient method of getting rid of these foreign impurities.

There is one direction, however, in which improvement is possible and where, happily, some has already taken place. Church, as early as 1886, condemned the throwing away of the water in which rice is boiled as this involves the loss of some mineral matter in which rice is notoriously deficient. It may be noted in passing that in the well regulated households of ryots, this is not thrown away but fed to the cattle. Fortunately now-a-days special contrivances designed on the basis of steam sterilizers, are being patented in Bengal, where no more water is used in cooking rice than can be absorbed by it. This certainly is an improvement in the right direction.

SUMMARY.

1. The composition of the rices of Bihar and Orissa is in the main similar to that of other rices analysed by previous workers. They approach, however, those of Burma more closely than they do the rest.

2. With an increase in the albuminoid content of husked rice there is a diminution in the quantity of soluble carbohydrates. On the other hand the low content of albuminoids is associated with increased amounts of soluble carbohydrates. When expressed as percentages of the dry matter, the sum of the albuminoids and soluble carbohydrates generally lies between 94 and 95.

3. The amount of phosphoric acid in a sample of husked rice is just a little less than half of the minerals present. The amount of potash is about half the quantity of phosphoric acid.

4. When rice undergoes polishing it loses much of the oil, or ether extract, and the minerals, besides some albuminoids. In the outer layers removed during this process the concentration of phosphoric acid

[1] *Analyst*, 1906, 40; *E. S. R.*, xvii, 1905-6, p. 996.

is greater than that of potash, although there is relatively more of both these constituents in the bran than in the polished grain. The nitrogen is more uniformly distributed.

5. No relation can at present be traced between the chemical composition and the accepted culinary properties of the different rices.

6. The dietetics of rice have been discussed. The greater acceptability of highly milled rice is attained at considerable loss of mineral substances. The use of these products requires greater attention to the mode of preparation of rice for the table and more careful consideration of the remainder of the diet than was necessary in the days of more primitive milling processes.

APPENDIX.

Composition of milled rices, Calcutta.

Variety	Weight in grams of one litre rice	GRAMS PER 100 GRAMS AIR-DRY RICE									
		Moisture	Ether extract	Albuminoids	Soluble carbo-hydrates	Woody fibre	Ash	Nitrogen		Phosphoric acid	Potash
								Albumi-noid	Total		
Dadkhani	855	9·62	0·30	5·32	84·05	0·10	0·61	0·83	0·85	0·27	0·19
Balam	833	9·88	0·23	8·76	79·96	0·25	0·92	1·38	1·40	0·44	0·19
Boiled Rangoon	893	9·51	0·10	7·01	82·54	0·10	0·74	1·10	1·12	0·34	0·07
Boiled Patna	820	10·66	0·18	7·25	81·01	0·13	0·77	1·14	1·16	0·38	0·14
Boiled Nagra	848	8·81	0·10	5·87	84·42	0·05	0·75	0·93	0·94	0·32	0·07

Variety	GRAMS PER 100 GRAMS DRY MATTER								
	Ether extract	Albumi-noids	Soluble carbo-hydrates	Woody fibre	Ash	NITROGEN		Phos-phoric acid	Potash
						Albumi-noid	Total		
Dadkhani	0·33	5·88	3·01	0·11	0·67	0·92	0·94	0·30	0·21
Balam	0·26	9·69	88·75	0·28	1·02	1·53	1·55	0·49	0·21
Boiled Rangoon	0·11	7·76	91·20	0·11	0·82	1·22	1·24	0·38	0·08
Boiled Patna	0·20	8·13	90·65	0·15	0·87	1·28	1·30	0·42	0·16
Boiled Nagra	0·11	6·44	92·57	0·06	0·82	1·02	1·03	0·35	0·08

A Modified Method of Green-Manuring.

IN a previous Bulletin [1] of this Institute a suggestion was made that green crops instead of being ploughed or buried by other methods directly in the soil on which they had been grown, should first be treated in such a way as to bring them into a more suitable condition for use as manure. This suggestion was based upon experimental results obtained mainly in the laboratory and as it has now been supported, and the conclusions upon which it depended have been confirmed by field results as well as by further laboratory work, it is here proposed to give some account of the method and of such results as have been obtained up to the present. It should, however, be clearly understood that the writer's principal object in publishing is to invite criticism and suggestions as to the practicability of the method and the possibility of its application to various crops (not necessarily grown as green manures), from agricultural officers throughout India, whose experience as practical agriculturists will enable them to decide as to the possible applications of the method in their own districts and to make such modifications as particular cases may require.

Principles of the method. It was found by laboratory and field experiments, as recorded in the abovementioned Bulletin, that the complete decomposition of a green crop depended upon the incidence of the rainfall following its burial; this being frequently defective, it is proposed to avoid negative results from green-manuring by carrying out the initial stages of decomposition under artificial conditions. It is here assumed that a negative result will be obtained from green-manuring if decomposition does not proceed in such a way and to such a degree as to result in the conversion of the organic nitrogen of the green manure into nitrate, (or in the case of certain crops, such as rice, into ammonia) and the breaking down of the cellulose and lignified tissues so as to result in the addition of humus to the supply already present in the soil. Failing such complete decomposition the buried crop will mainly contribute to that inert organic fraction which plays a comparatively unimportant part in the life of the soil, as compared with the active portion furnishing food for bacteria, fungi, and plants and profoundly modifying its physical character. It was found that the most complete breaking down and subsequent nitrification of the plant tissues was obtained by providing an excess of moisture accompanied by anaerobic conditions during the first stage, followed by a second one of less moisture and semi-anaerobic

[1] Hutchinson, C. M. Green-Manuring Experiment, 1912-13. *Bulletin No. 40, 1914, of the Pusa Agricultural Research Institute.*

conditions. It is to be understood that complete anaerobism is not attained nor aimed at, but only a condition favourable to the development of that class of organisms whose specific function is the breaking down of the cellulose walls and middle lamella, the resistance of which to decay under aerobic conditions indefinitely prolongs the decomposition of buried green manures and organic residues in a soil containing an insufficiency of moisture.

One of the advantages connected with Indigo culture is the use as manure of the by-product of manufacture locally known as *seet*; this is the indigo plant partly fermented in water during extraction in the factory and partly in heaps after removal from the vat. The resulting product is a partly decomposed mass of vegetable tissue which possesses high manurial value, although in cases where it is taken direct from the factory to the land this does not show its greatest effect until the following season, whereas when allowed to remain in heaps for a further period of several months its action is rapid and immediate. This different effect is partly due to more complete decomposition and partly to the formation of toxic bodies during the early stages of fermentation which are decomposed by oxidation at a later period. Here we have then a case where a leguminous green manure is carried through the earlier stages of decomposition under artificial conditions which provide the necessary supply of water and the semi-anaerobism required. It is obvious that any green crop treated in a similar manner may give results which will compare with those produced by indigo *seet* in proportion to their relative nitrogen content, so far as this element is responsible for beneficial results; it must be remembered however, that the benefits of green-manuring are by no means confined to the provision of nitrogenous food, but that they also depend upon the production of humus in the state above referred to, so that many crops of low nitrogen content may advantageously be treated in such a way as to attain this condition. Comparatively few have been experimented with at Pusa, mustard being one of them, and it is in order to obtain suggestions on this point, and to suggest the carrying out of experiments in other parts of India, that this description of the method is being put forward.

Sann hemp (Sannai, *Crotalaria juncea*) is the most commonly used green manure in North Bihar. When turned in in the ordinary way with the plough its effect on the succeeding *rabi* crop depends upon the incidence of the rainfall. It is always necessary to cut it down before attaining its full growth and to allow a considerable period of time between burying and planting the *rabi* crop. This is necessitated by the possible lack of moisture in the soil during the decomposition period between burying and planting of the succeeding *rabi* crop

partly due to the large amount removed by the crop itself by transpiration, and by the difficult decomposition of the more mature crop. It will be seen by reference to the Bulletin (*loc. cit.*) that the amount of nitrogen per acre added to the soil by burying sann hemp is greater in the case of the ten weeks old plant as compared with that of six weeks growth in about the ratio of 88 to 69, so that a proportionate loss of nitrogen added to the soil in this form results from early burial. Similarly, a total loss of green manure crop in the proportion of 58 in the ten weeks to 45 in the six weeks old crop results in this reduction in the amount of humus turned into the soil, when early cutting is resorted to in order to ensure proper decomposition. That such early turning in of the green crop is necessary or at least advisable under ordinary conditions is shown by the relative rates of nitrification of young and of mature plants as described in the Bulletin (*loc. cit.*) and one of the advantages of the new method lies in the possibility of dealing successfully with a fully matured and consequently heavier crop.

The method. Borrow pits were dug at the sides of the field previous to cutting the green crop ; this being done during the rains the pits filled with water ; the cut crop was placed in the pits, left there for periods varied experimentally from 24 to 48 hours, removed from the pits, stacked in heaps and allowed to ferment for varying periods of time, after which the rotted manure was applied to the soil.[1]

It was at first found necessary to water the heaps occasionally to prevent drying out, but this was subsequently avoided by plastering their outsides with clay, comparatively small quantities of water being occasionally applied to prevent cracking of the latter.[2]

Further modifications of this method were adopted subsequently ; in order to avoid loss of nitrogen as ammonia, the water remaining in the pits was used for moistening the heaps, and the soil at the bottom of the pits was dug out and made into alternate layers with the green manure in the heaps. As large quantities of ammonia pass into the water during fermentation the smallest possible quantity of water should be used so as to make it possible to utilize the whole of it for moistening the heaps.

[1] Recent experiments carried out in this laboratory in connection with the fermentation in water of indigo and other leguminous plants have shown that in many cases, although not in all, the character of the bacterial fermentation in water is such as to result in the liberation of large quantities of nitrogen gas representing a corresponding loss of this manurial constituent. For this reason it would appear advisable to omit altogether the preliminary steeping in water and commence the preparation of the fermented manure by stacking in heaps, moistening with water, and allowing fermentation to proceed as before.

[2] This method is largely used by the Chinese, who prepare the green manure used in rice fields (mostly *Astragalus*) by making it into heaps and plastering the latter with clay taken from the irrigation channels.

It was found that more complete fermentation could be obtained by inoculating the heaps with impure cultures of cellulose destroying bacteria obtained simply by making a water extract of fresh cowdung.[1]

It will be seen from the above description of the method that its main object is to obtain more complete decomposition of the organic matter than can be arrived at by the ordinary process of burying, this result being achieved by introducing anaerobic conditions in the early stages. Variations of the method should be made to suit local conditions, merely keeping the general principle in view in so doing.

It appears to the writer that certain advantages are connected with the use of this method as compared with the ordinary practice, and that they may in many cases more than balance the extra cost of the labour required for carrying it out.

Advantages of the method. The principal advantage of the method, as tested at Pusa, has been the immediate return from the green manure treated in this manner, as compared with that from sann hemp buried in the ordinary way. In some cases during the first season of trial this result was not so marked owing to want of complete knowledge of the various factors underlying the action of the material produced; thus, too long soaking in water in some cases resulted in loss of nitrogen as ammonia, and too early use of the manure, combined with inappropriate methods of burying it in the soil, failed to secure freedom from toxins formed during fermentation and inimical to nitrification and fertility. In such cases fertilizing action was delayed in the same manner as occurs when fresh indigo *seet* is used injudiciously, the full return from the nitrogen applied not becoming apparent in the *rabi* crop, but following in the *kharif* one or even in the succeeding *rabi* of the following season. This is a not uncommon result of the use of indigo *seet* and is generally looked for in the case of green manure, although in the writer's experience it is not uncommon for the latter to fail entirely to show any positive result if the rainfall is unsuitably distributed or in defect. With properly fermented green manure applied at the right time positive results will be obtained provided the soil moisture is sufficient to supply the needs of the extra growth following from its use.

[1] This method is particularly successful when used for preparing a rapid acting nitrogenous organic manure from oil cake, the latter being mixed with one quarter of its weight of soil and a small proportion of bone dust (from 2—5 per cent.) or superphosphate, watered with extract of cowdung, made into a heap, saturated with water, then covered with soil, kept moist and allowed to ferment for 2—3 weeks. The resulting manure is an excellent one for turf or garden plants, and depends for its rapidity of action upon the semi-anaerobic decomposition set up in the heaps. It should be noted, however, that before use in the garden it must be exposed to the air for at least a week to oxidize the bacterio-toxins produced during fermentation; this is not necessary in the case of turf, but the rate of application must be regulated to allow of oxidation proceeding *pari passu* with incorporation into the soil.

The immediate action of fermented sann hemp was shown in experimental plots of $\frac{1}{24}$th of an acre sown with oats. Here the fermented manure was concentrated by application to half the area on which it was grown. Such concentration forms part of the method and constitutes one of its advantages, and will be discussed separately.

The resulting figures were : –

Treatment	Grain	Straw	
Control	885	2,820	lb. per acre.
Sann hemp	960	2,835	
Fermented sann hemp . . .	1,540	2,970	

The control area was not completely unmanured as it had the advantage of retaining the roots and stubble of the crop of sann hemp which was grown on it and used after fermentation to add to that on the fermented manure plot.

This experiment was repeated in the following season both with oats and tobacoo, but in this case the results were modified by the fact that the amount of soil moisture present varied from an optimum amount in the plots forming one row at the north end of the field down to a quantity obviously insufficient for full growth at the south end. The plots were arranged in triplicate in three rows running east and west, so that, in the north row the moisture was good, in the middle row it was slightly in defect, and in the south row decidedly so. The results varied in accordance with this difference. In the north row there was but little difference in crop between the plots which had had sann hemp buried and sann hemp fermented, the moisture present being sufficient to ensure decomposition of the green manure, whereas in the south row the fermented manure produced a considerably higher return than the buried green crop.

An experiment on qualitative lines was carried out by the Imperial Agriculturist at Pusa during the *rabi* season 1915-16. In this experiment mustard stalks were fermented and applied to land on which a very large crop of oats was afterwards obtained. This is an example of the use of a crop other than a leguminous one for this purpose, and Mr. Milligan is of opinion that there are other cases such as sugarcane stools, and Arhar (*Cajanus indicus*) leaves, in which the method may be applied with advantage.

An experiment on tobacco manuring was carried out in 1915-16 with fermented sann hemp in order to determine the effects of different methods of preparation and of application of this material.

Preparation. Two methods of preparation were adopted :—

(*1*) *Aerobic*, in which the green manure was fermented in heaps kept moist but not covered with clay.

(2) *Anaerobic*, in which the heaps were plastered with clay.

The sann hemp was first cut into short lengths and soaked in water in a pit for 24 hours. It was then removed from the pit and transferred to another shallow one, in this case about one foot deep and eight feet square.

Aerobic fermentation. In this method the soaked material was arranged in alternate layers of *sann* and soil, the former about 3 inches and the latter about ½ inch in thickness. The whole heap was then covered with a layer of soil about 3 inches thick and finally with one of straw to prevent evaporation. Watering was carried out about once a week, sufficient water being added to keep the top layer moist.

Anaerobic fermentation. The heaps were arranged in the same way, but each layer was consolidated by treading down, and the whole heap was finally plastered with clay about one inch thick.

Fermentation was carried on from 15th August to 5th October 1915 (about 48 days), after which the heaps were opened up and the fermented material transferred direct to the soil of the experimental plots.

Application. The preparation of the fermented manure was not carried out in time to allow of its application to the soil sufficiently early to entirely avoid toxic effects. Two methods of application were adopted in order further to test the existence of toxins in the anaerobically prepared material.

(*a*) In these plots the manure was buried in furrows, the plants being placed in intervening ridges.

(*b*) In these the manure was buried in the ridges, the plants being in the furrows.

The fermented manure was applied at rates which represented concentrations of 3 : 1 in one series and 6 : 1 in the other, *i.e.*, the amount used on one acre was prepared from the green manure crop cut from three acres in the first and from six acres in the second.

The results are given in the following table :—

Tobacco manuring with fermented sann hemp.

No. of Plots	Treatment	Green leaf		Pounds per acre	
		Furrow (*b*)		Ridge (*a*)	
		lb.	Increase lb.	lb.	Increase lb.
1	No manure	11,252	..	9,609	..
	Fermented *Sann* anaerobic 3 : 1	12,022	770	11,500	1,891
	Fermented *Sann* aerobic 3 : 1	14,550	3,298	13,548	3,939
	Fermented *Sann* anaerobic 6 : 1	14,898	3,646	16,118	6,509

In these plots the superiority of the aerobically fermented manure over that prepared anaerobically is obvious ; there is reason to believe, however, from other observations, that this would not invariably be the case, especially in view of the fact that the manure was not allowed any opportunity of aeration after fermentation and before burying in the soil. The plants in the ridges gained an advantage in this respect from the fact that their feeding roots did not reach the manure so early as did those of the furrow planted seedlings, as well as from the better aerated soil in the ridges in which they made their early growth, before drying out of the soil had taken place to any extent. When this began to occur the roots had reached the buried manure and were not only benefiting by the nitrogen supply derived therefrom but from the moisture-holding power of the well rotted vegetable matter, to which reference has already been made.

With regard to the difference in character of the anaerobic and aerobic preparations, it was found that when first taken from the heap the former contained no nitrate but a considerable amount of ammonia (recoverable by distillation with magnesia although not free). A water extract of the material was toxic to seedlings, but this condition was changed and nitrate formation took place after aerobic conditions were introduced, more complete nitrification of the organic nitrogen present being eventually obtained than was the case with the aerobically prepared material. This was in accordance with the laboratory observations of the previous year, and confirms the conclusion as to the possibility of preparing a more rapid acting manure by this method, keeping in view, however, the necessity for interposing an aerobic stage between the anaerobic preliminary one and the final application to the soil, not only to promote nitrification, but to ensure the oxidation and destruction of the toxins produced.

In some cases, for example where irrigation is practised, it might be more convenient to make use of a different application of the method. When the fermenting material is allowed to remain in the soaking pit, instead of being removed from the water after 24 hours' immersion, decomposition proceeds with liberation of ammonia which goes into solution in the water. This ammoniacal water is known in Bihar as *seet water* and was formerly allowed to run to waste, but is now conveyed by drainage channels on to arable land as a fertilizer. It was found on experimental oat plots that such *seet water* prepared from sann hemp was of great fertilizing value, the ammoniacal and other nitrogen contained in it becoming rapidly available as plant food ; the residual effect, however, as was expected, was practically nil. It was further found that decomposition of the green material whether sann hemp, cut grass, mustard

or maize stalks, proceeded for several weeks under water, the latter being drawn off periodically (at weekly intervals) and used to fertilize soil, the same amount of fresh water being added to the pit. After some four to six weeks, depending upon the temperature, the remaining water was drawn off and the residual material was then found to be completely broken down into a fine material closely resembling well rotted farmyard manure, greatly reduced in bulk but containing a fair percentage of nitrogen which readily nitrified in soil.

The *seet water* prepared in this manner was also used here for fertilizing turf and produced very similar results to those obtained with sulphate of ammonia, possessing one notable advantage over the latter, however, in not requiring the presence of considerable quantities of lime in the soil. It has been found at Pusa that the cut grass from the golf course can be used to fertilize the putting greens by preparing *seet water* in this way, and the method is recommended as the most economical and efficient one known to the writer. The one drawback to its use in proximity to dwelling houses is the unfortunate odour ; this can be overcome by careful additions of copper sulphate (0·625 per cent.) and potassium cyanide (sufficient to prevent precipitation of the copper as sulphide) to the water in the pit ; this addition in these proportions prevents the formation of bad smelling compounds such as indol and skatol, but does not inhibit ammonification.[1]

It is suggested therefore that in irrigation areas distribution of the nitrogenous content of the green manure made available by fermentation might be carried out more easily and economically so far as labour is concerned, by allowing fermentation to proceed in water in the above described manner and conveying the ammoniacal water thus produced to the land by means of the irrigation channels.

The residual solid material, by reason of its loss of weight and complete disintegration, will be found easy to handle as compared with the incompletely fermented manure.

The principle underlying the use of this method, *i.e.*, the more complete decomposition of organic manures by the provision of anaerobic or semi-anaerobic conditions during the early stages of this process, may be made use of in the treatment of soil to which such organic manures have already been added ; thus in a field experiment in which the toxic effect of water-logging a soil containing added organic matter (in this case mustard cake) was tested, it was found that by regulating the water supply it was possible to produce complete decomposition

[1] Since writing the above it has been found that Arhar (*Cajanus indicus*) refuse, after threshing, yields on fermentation a completely odourless manure. This is apparently due to the presence in the tissues of this plant of certain compounds which control the character of the bacterial fermentation.

of the added cake and yet to avoid the toxic condition by providing proper drainage. The very greatly increased growth on this watered and drained plot as compared either with one receiving less water or one receiving more, was not due merely to the use of the optimum amount of water required to produce the best physical condition of the soil nor for supplying the plants, as the former was allowed to dry out and was thoroughly cultivated before sowing in all three plots ; moreover the differences in growth which eventually occurred did not become apparent for some weeks after germination, when the roots of the plants had got down into a layer which in the undrained plot contained toxins, and in the drained one, available plant food. Similar variations in the water supply produced no such results when nitrogen was applied in the form of ammonium sulphate, confirming the conclusions above mentioned.

A further advantage of the method lies in the possibility of applying the fermented manure at the rate per acre at which experience has shown it will do the most good to the particular soil or crop which it is intended to benefit. This is an aspect of the case which the writer feels some diffidence in enlarging upon, but it appears that there must be an optimum rate per acre for the application of any manure to any one soil for the benefit of any particular crop, and judging by experience with green manures in tea soils and with indigo *seet* as a manure for tobacco, oats, and maize, the rate per acre most likely to produce not only immediate returns in crop increase, but permanent improvement in soil condition, is far removed from that secured by merely turning in a green crop on the area upon which it has been raised. Indigo *seet* is very generally applied at a concentration rate of about ten to one, *i.e.*, the crop from ten acres of indigo land is made into *seet* and returned on to one acre of tobacco or other land. This appears an unnecessarily high ratio, the increases in the tobacco experiment above described having been above the normal return from *seet* with a three to one ratio and still larger with a six to one. Experience is required not only to determine the profitable rate per acre for various crops, but the best fermentation periods and more especially the best times of application. There can be little doubt, however, that in a large number of cases the mere concentration of the green manure up to an effective rate per acre for nitrogen as a crop stimulant gives the cultivator a degree of control in this direction which the burying of a green crop in the ordinary way could not secure, whilst the no less important amelioration in the condition of the soil due to the addition of considerable quantities of well-rotted organic matter will play an important part in its permanent improvement and general fertility. It may further

be pointed out that in some cases it may be found advantageous to grow the green crop on one area and apply it to another, thus poor waste, or jungle lands might be made to contribute to the fertility of better soils under arable cultivation. This point, however, is one which can be dealt with more effectively by agricultural experts, whose advice on the subject will be welcomed by the writer.

It is suggested, then, that the use of the above described method, modified to suit local conditions, will be found to remove the practice of green-manuring from the fortuitous region of dependence upon rainfall to one in which its proper use will place it on a level with such comparatively expensive fertilizers as oilcake and cattle manure.

PUSA,
April 1916.

APPENDIX.

A Note

by

S. MILLIGAN, M.A., B.Sc.,

Imperial Agriculturist.

Mr. Hutchinson's Bulletin will be read with considerable interest by agriculturists generally. After all the main agricultural problems are connected with the maintenance of the fertility of the soil. The practice of green-manuring as a means towards this has been largely and widely advocated for some considerable time, and although success has been almost uniformly attained in puddled rice lands where transplantation is practised the results, as applied to other crops, have been very variable. As pointed out by Mr. Hutchinson the main and controlling factor appears to be the incidence of rainfall after the green crop has been buried. Not only neutral but often negative results are obtained by even a partial failure of the autumn rains following on the burial of green crops such as sann hemp.

Although I am still doubtful as to whether Mr. Hutchinson's proposal to remove the crop from the ground, rot it in pits, and then apply it to the land, will be found to be economically possible owing to the amount of labour involved—the method has the following distinct advantages most of which are mentioned in the Bulletin :—

(1) In case of the failure of the autumn rains and consequent lack of moisture in the soil the manure can be held over till the following crop.

(2) The improved method of rotting the manure will enable the grower to postpone the cutting of the crop and thus obtain a much larger bulk of manure.

(3) The possibility of applying larger and consequently more paying quantities of the manure per acre. It has been clearly demonstrated at Pusa that homœopathic doses of manures are economically unsound.

(4) The application of the manure in a better digested form will increase the amount of *available plant food* at an early stage of growth of the succeeding crop. From my own observations I have come to the conclusion that most of the *rabi* cereals require for the production of a full outturn of grain, a sufficient amount of available nitrogenous plant food at a very early stage of their growth. The

addition of such plant food at a later stage, although it may assist in the proper fertilization of the flowers, obviously cannot increase the maximum possible outturn of grain which is determined at an early stage of the plant growth, in fact at the period that the plant is tillering and forming its ears.

As a matter of practical experience it is known that while late application of nitrogenous manures may increase the straw outturns considerably, they have no corresponding effect on that of the grain. A green manure crop, then, decomposing (and producing plant food) at too late a period would have its main effect on the straw. On two occasions during the last four years at Pusa this has happened, the failure of the *hathia* or October rainfall, followed by abnormal heavy winter rain, having produced bulky crops of wheat and oats with no corresponding grain yield on the green-manured fields. Mr. Hutchinson's figures on his small plots are instructive. The plot with fermented sann hemp, although giving over 50 per cent. more grain than the others, gave practically the same amount of straw.

The economics of the proposed method could be best worked out by comparing it for a series of years with—

(1) A green crop buried in the usual way,

(2) The application of nitrogenous manures other than cowdung.

There is another aspect of the subject, and that is the application of Mr. Hutchinson's method to the decomposition of organic matter such as the stalk and root residues of crops. I have already had experience of the value of this method in connection with the use of fermented *sarson* stalks and Arhar (*Cajanus indicus*) leaves. In every province of India there are doubtless similar sources of organic matter which could be utilized and would be of considerable value if properly treated. For example in most sugarcane tracts the stools have to be collected and burnt before a succeeding crop can be grown. It would involve little additional labour to pit and rot them. These stools contain a considerable amount of saccharine matter and would possibly form an excellent medium for bacteria.

PUSA,
April 1916.

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Rinderpest.

Preparation of Anti-serum.[1]

[*Received for publication on 1st July 1916.*]

DURING the past ten years the procedures adopted in the preparation of anti-rinderpest serum at the Muktesar laboratory have been frequently revised and improved as the result of experiments directed to finding a means of raising the potency of the serum and effecting economies in its manufacture. The latter consideration became more urgent as the demand for serum increased owing to the supply of susceptible hill cattle, employed in its production, being strictly limited; the introduction by Holmes [2] of plains buffaloes for serum making greatly lessened this difficulty but hill cattle were still necessary for maintaining and furnishing the rinderpest virus for hyperimmunization and as test animals in the standardization of the serum.

In 1914-15 the issues of anti-rinderpest serum rose to 13,88,560 doses at 5 c.c. per dose, and the demand for anthrax and hæmorrhagic septicæmia sera also greatly increased. Difficulties of accommodation and fodder supply for the cattle now made it necessary to ascertain whether, in view of a possible further rise in the demand, any modifications of the existing methods could be effected with the object of increasing the yield of serum proportionately to the number of cattle employed.

A comparative study of the yields resulting from different methods of separating the serum from the blood was undertaken by Dr. Norris,[3] Physiological Chemist of the Muktesar laboratory, and as a result of his investigation, a combined centrifuging and clotting method has been introduced in place of the former practice of defibrinating the blood before centrifugalization.

Recent observations in the preparation of anti-diphtheritic, antitetanic and other sera have shown that antitoxin content reaches its maximum from five to seven days after injection of the antigen (toxin, culture, etc.) into the serum-making animal and that from this time the potency of the serum falls fairly rapidly.

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[1] Results arrived at in October 1915.

[2] Holmes, J. D. E., Rinderpest. *Indian Civil Veterinary Department Memoir* No. 3, 1911, p. 98.

[3] Norris, R. V. A comparison of the "Defibrination" and "Oxalate" methods of serum preparation, *Bulletin No. 60, Agri. Research Institute, Pusa.*

Little attention appears to have been given to this point in the case of anti-rinderpest serum but since a reduction of the interval between injection and bleeding would effect a saving both in the cost of feeding and in the number of animals required for serum making, the matter is one of some importance when a large output of serum has to be maintained.

The early workers on anti-rinderpest serum allowed a considerable interval to elapse between the last injection of virulent blood and the first bleeding for serum but there is a curious absence of precise information on this point in their reports ; the bleedings were usually continued at intervals of from seven to ten days for three or more bleedings.

Kolle and Turner [1] in their report to the Secretary for Agriculture, South Africa, give no details of the actual bleedings when describing the method of preparation of the serum, nor does Turner [2] furnish particulars on this point. Rogers,[3] who states that he followed the method of Kolle and Turner, merely remarks that bleedings were made once a week for three weeks.

Lingard [4] in describing his rapid method of preparing serum states that the first bleeding was taken 14 days after the termination of the reaction following injection ; and adds " If the reaction lasted 8 days, bleeding would be performed for the first time on the 22nd day after the injection of virulent blood." This method of allowing an interval of three weeks after injection and then bleeding weekly, was followed at the Muktesar laboratory up to the year 1911 when Holmes [5] showed that a more potent serum was obtained by bleeding at 14 to 16 days after injection of the virulent blood and giving a second bleeding two days later ; he adopted this procedure of two bleedings after each injection as the routine method for serum manufacture and it has been in operation up to the present time.

At the serum laboratory of the Bureau of Agriculture, Philippine Islands, Jobling [6] adopted the method then practised at Muktesar ; he states: " Following Roger's plan the animals after receiving 1000 c.c. of virulent blood are allowed to remain until the temperature becomes normal. They are then bled three times with an interval of

[1] Kolle and Turner. Report on progress of Research Work at Kimberley, *Veterinary Journal*, Vol. XLV, 1897, p. 462.

[2] Turner, G. Rinderpest in South Africa, *The Journal of Tropical Veterinary Science*, Vol. 1, 1906, p. 269.

[3] Rogers, L. Report on Rinderpest, 1900, p. 89.

[4] Lingard, A. Report on Rinderpest, 1905, p. 13.

[5] Holmes, J. D. E. *Loc. cit.*

[6] Jobling, J. W. Preliminary Report on the Study of Rinderpest, *Bulletin No. 4*, *Bureau of Government Laboratories, Manila, Philippine Islands*, 1903, p. 17.

one week between each bleeding." But the length of time considered necessary before taking the first bleeding is not stated.

Later reports from the same laboratory by Ruediger [1] and Ward and Wood [2] describe the method of serum preparation that is followed and give seven to ten days as the interval allowed between injection and the first bleeding, two further bleedings being taken at intervals of one week.

No reference has been found to any experiments designed to ascertain the potency of serum taken at varying intervals after inoculation of virulent rinderpest blood.

Holmes [3] tested the value of serum from first, second and third bleedings from plains bulls, hill bulls and buffaloes. Three animals were used in each case for the production of the serum and the bleedings were taken on the 15th, 18th and 23rd days after injection but as the sera from the different bleedings were not tested at uniform doses it is difficult to make any satisfactory comparisons from the results.

The series of observations described in this paper were carried out to ascertain the potency of sera taken 8, 12 and 16 days after the injection of virus and to compare the results with those given by sera taken 15 and 17 days after injection ; the latter intervals were those allowed in the routine method of serum manufacture followed at the Muktesar laboratory, the bleedings being taken at the rate of 6 c.c. and 8 c.c. per lb. body weight respectively. The three bleedings at four days intervals were all taken at the rate of 6 c.c. per lb.

Previous experience had shown that cattle would stand bleeding to this extent with little or no interference to their health and it seemed probable that the potency of the sera from the second and third bleedings would not be found to diminish as rapidly as when intervals of a week are allowed between the bleedings ; the saving in time would also be a consideration. Tests were made of the potency of the mixed sera from the two series and were repeated on a large scale using both hill bulls and buffaloes for serum production.

As the main purpose of the experiments was to provide an increased yield of serum which should be at least of equal potency to that prepared by the existing routine method, records were kept of the amounts of serum obtained at each bleeding and the total yields given under the two systems were compared.

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[1] Reudiger, E. H. Observations on Cattle Plague, *The Philippine Journal of Science*, Vol. IV, s. B., No. 5, 1909, p. 384.

[2] Ward, A. R. and Wood, F. W. Experiments on the Efficiency of Anti-Rinderpest Serum, *Bulletin No. 19, Bureau of Agriculture, Manila, Philippine Islands*, 1912, p. 19.

[3] Holmes, J. D. E. Rinderpest. *Memoirs of the Department of Agriculture in India. Veterinary Series*, Vol. II, No. 2, Nov. 1913, p. 55.

Throughout the experiments the potency of the sera was tested on susceptible hill bulls, six for each test, by injecting them simultaneously with virulent rinderpest blood and graduated quantities of the serum.

In the routine serum testing, doses of 36 c.c., 72 c.c. and 108 c.c. per 600 lb. body weight, two bulls at each dose, are employed, these amounts being equivalent to 2 c.c., 4 c.c. and 6 c.c., respectively in the case of plains animals [1]; but in order to gain a more accurate estimate of the relative values of the sera, the doses throughout the experiments were fixed at 27 c.c., 54 c.c. and 81 c.c. per 600 lb. body weight, equal to $1\frac{1}{2}$ c.c., 3 c.c. and $4\frac{1}{2}$ c.c. respectively for plains cattle.

At each test two hill bulls were inoculated with virulent blood alone to serve as controls; after developing symptoms of acute rinderpest these were bled to death to provide virulent blood for hyperimmunization.

EXPERIMENT I.

To compare the values of sera taken 8, 12 and 16 days after the injection of virulent rinderpest blood with those of sera taken 15 and 17 days after a similar injection.

Ten hyperimmune serum-making hill bulls were selected and divided into two series, A and B, so that the five animals of each series had received an approximately equal number of previous injections and bleedings.

All were injected on the same day with a mixture of virulent rinderpest blood and potassium citrate solution, the doses, which varied from 8 to 10 c.c. of the mixture per lb. body weight, being regulated according to the number of previous injections the animals had received.

The animals of series A were bled 8, 12 and 16 days later at the rate of 6 c.c. per lb. body weight and the sera labelled A 1, A 2 and A 3 respectively.

The animals of series B were bled on the 15th day at the rate of 6 c.c. and on the 17th day at the rate of 8 c.c. per lb. body weight; the sera being labelled B 1 and B 2 respectively.

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[1] For convenience of issue the standardized dose of serum for plains cattle is taken at 5 c.c. per 600 lb. body weight though owing to the varying susceptibility possessed by different animals this only applies to the least susceptible; in other cases more than a single dose must be employed. Owing to their uniform high susceptibility hill bulls are most suitable for test purposes and as observations have shown that they require eighteen times the dose of serum necessary for plains animals of low susceptibility, the test doses are fixed accordingly; only serum which protects hill bulls at 72 c.c. or less per 600 lb. body weight (equal to 4 c.c. for plains cattle) is issued.

Serum-making Bulls.

SUMMARY.

SERIES A.—*Three bleedings at 6 c.c. per lb. body weight.*

Hill Bull No.	Virulent blood and potassium citrate injected c.c.	Bled on 8th day c.c.	Total Serum A 1. c.c.	Bled on 12th day c.c.	Total Serum A 2. c.c.	Bled on 16th day c.c.	Total Serum A 3. c.c.
3,385	2,400	1,900		1,900		1,900	
4,047	2,000	1,600		1,700		1,700	
3,925	2,000	2,100	4,250	1,700	4,950	1,500	5,500
3,279	2,600	2,000		2,000		2,000	
4,024	1,600	1,300		1,500		1,400	
TOTAL	10,600	8,900	4,250	8,800	4,950	8,500	5,500

SERIES B.—*Two bleedings at 6 c.c. and 8 c.c. per lb. body weight respectively.*

Hill Bull No.	Virulent blood and potassium citrate injected c.c.	Bled on 15th day c.c.	Total Serum B 1. c.c.	Bled on 17th day c.c.	Total serum B 2. c.c.
4,674	1,200	900		1,400	
3,851	2,200	1,800		2,500	
4,473	2,200	1,600	3,250	2,100	4,500
4,493	1,800	1,500		2,100	
4,311	1,800	1,400		1,900	
TOTAL	9,200	7,200	3,250	10,000	4,500

Tests of Sera A1, A2, A3, B1 and B2.

SUMMARY.

SERUM A1.—*Test animals and controls inoculated with 0·5 c.c. virulent blood from hill bull No. 5333—temperature 40° C., vesicles 6th day of attack.*

No. of test animal, Hill Bull	Age yrs.	Weight lb.	Dose per 600 lb. weight c.c.	Actual Dose c.c.	Maximum temperature reaction	Vesicles	Result
5,357	3	194	27	8·8	40·5	10th day	Moderate reaction. Recovery.
5,355	3	210	27	9·5	39·6	nil	Slight reaction. Recovery.
5,358	1½	186	54	16·8	40·2	8th day	Moderate reaction. Recovery.
5,356	4	216	54	19·5	40·3	11th day	Moderate reaction. Recovery.
5,359	3	172	81	23·2	39·0	nil	No reaction. Recovery.
5,354	3½	226	81	30·5	40·1	nil	Very slight reaction. Recovery.

Controls.

Hill Bull 5360. Severe attack, temperature 39·6°C. Vesicles 8th day. } Bled to death
Hill Bull 5361. Severe attack, temperature 40·6°C. Vesicles 8th day. } 9th day.

SERUM A2.—*Test animals and controls inoculated with 0·5 c.c. virulent blood from hill bull 5718, temperature 40·3°C., vesicles 6th day.*

No. of test animal Hill Bull	Age yrs.	Weight lb.	Dose per 600 lb. weight c.c.	Actual Dose c.c.	Maximum temperature	Vesicles	Result
5,747	3	176	27	7·9	40	nil	Moderate reaction. Recovery.
5,749	1½	176	27	7·9	40·6	,,	Moderate reaction. Recovery.
5,750	2	180	54	16·2	39·3	,,	Slight reaction. Recovery.
5,746	2	190	54	17·1	40·5	,,	Moderate reaction. Recovery.
5,377	3	188	81	25·4	40·5	,,	Slight reaction. Recovery.
5,372	2	200	81	27	39·7	,,	Slight reaction. Recovery.

Controls.

Hill Bull 5756. Very severe attack, temperature 41°C. Vesicles 7th day. } Bled to death
Hill Bull 5755. Very severe attack, temperature 40·9°C. Vesicles 6th day. } 8th day.

SERUM A3.—*Tested with serum A2. Virulent blood from the same hill bull being employed.*

No. of test animal Hill Bull	Age yrs.	Weight lb.	Dose per 600 lb. weight c.c.	Actual Dose c.c.	Maximum temperature	Vesicles	Result
5,748	2½	172	27	7·7	40·3	nil	Moderate reaction. Recovery.
5,596	3	174	27	7·8	40·4	8th day	Died 13th day.
5,752	2	180	54	16·2	40·7	nil	Moderate reaction. Recovery.
5,751	3	196	54	17·6	40·4	,,	Moderate reaction. Recovery.
5,378	3	180	81	24·3	39·5	,,	Very slight reaction. Recovery.
5,380	2	192	81	25·9	40·7	,,	Slight reaction. Recovery.

SERUM B1.—*Test animals and controls inoculated with 0·5 cc. virulent blood from hill bull 5432, temperature 40°C., vesicles 6th day of attack.*

No. of test animal Hill Bull	Age yrs.	Weight lb.	Dose per 600 lb. weight c c.	Actual Dose c.c.	Maximum temperature	Vesicles	Result
5,480	2	170	27	7·6	41	nil	Moderate reaction. Recovery.
5,482	2	186	27	8·37	40·5	,,	Moderate reaction. Recovery.
5,481	4	210	54	18·9	39·8	,,	Slight reaction. Recovery.
5,479	6	298	54	26·8	39·8	,,	Slight reaction. Recovery.
5,478	5	406	81	54·8	40·5	,,	Slight reaction. Recovery.
5,477	12	412	81	55·6	40·7	,,	Slight reaction. Recovery.

Controls.

Hill Bull 5474. Severe reaction 40·1°C. Vesicles 6th day. Bled out 8th day.
Hill Bull 5475. Severe reaction 40·5°C. Vesicles 8th day. Bled out 9th day.

SERUM B2.—*The same virulent blood and controls as for Serum B1.*

No. of test animal Hill Bull	Age yrs.	Weight lb.	Dose per 600 lb. weight c.c.	Actual Dose c.c.	Maximum temperature	Vesicles	Result
5,488	3	174	27	7·8	40·5	nil.	Moderate reaction. Recovery.
5,486	3	180	27	8·1	40·7	8th day	Died 12th day.
5,487	4	200	54	18	40·0	10th day	Moderate reaction. Recovery.
5,485	7	240	54	21·6	40·0	nil	Slight reaction. Recovery.
5,484	12	318	81	42·9	39·5	,,	Slight reaction. Recovery.
5,483	10	378	81	51	40·2	,,	Slight reaction. Recovery.

CONCLUSIONS.

A comparison of the results of the above five tests shows that—

(1) the rinderpest antibodies were present in the serum of hyper-immune animals in full amount 8 days after the injection of virulent blood,

(2) at the second bleeding on the 12th day the antibodies were still present in sufficient quantity for 27 c.c. per 600 lb. body weight to protect hill bulls against the injection of virulent blood, which is equal to 1·5 c.c. per 600 lb. in the case of plains animals,

(3) the serum from a third bleeding four days later was still protective in doses of 54 c.c. for hill bulls or 3 c.c. for plains bulls per 600 lb. body weight,

(4) the serum from a first bleeding 15 days after the injection of virulent blood was fully protective in doses of 27 c.c. for hill bulls or 1·5 c.c. for plains bulls, but at a second bleeding on the 17th day the potency had fallen so that 54 c.c. per 600 lb. body weight were required to give full protection to hill bulls.

EXPERIMENT II.

To compare the value of the mixed serum obtained from three bleedings, 8th, 12th and 16th days after injection with that of serum from two bleedings taken on the 15th and 17th days.

The three sera A1, A2 and A3 of series A and the two sera B1 and B2 of series B were mixed separately in the proportions of the total yields from each bleeding and labelled A123 and B12 respectively; these sera were then tested at the same time.

Tests of Sera A123 and B12.

SUMMARY.

SERUM A123.—*Both sets of test animals and the controls inoculated with 0·5 c.c. virulent blood from hill bull No. 5519 temperature 40·6°C., vesicles 6th day.*

No. of test animal Hill Bull	Age	Weight	Dose per 600 lb. weight	Actual Dose	Maximum temperature	Vesicles	Result
	yrs.	lb.	c.c.	c.c.			
5,577	2½	146	27	6·5	39·6	nil	Slight reaction. Recovery.
5,575	3	162	27	7·2	40·8	10th day	Moderate reaction. Recovery.
5,576	2	168	54	15·1	39·8	nil	Slight reaction. Recovery.
5,573	3	181	54	16·2	40·8	„	Moderate reaction. Recovery.
5,574	1½	204	81	27·5	39·9	„	Very slight reaction. Recovery.
5,578	4½	224	81	30·2	39·8	„	Very slight reaction. Recovery.

SERUM B12.

No. of test animal Hill Bull	Age yrs.	Weight lb.	Dose per 600 lb. weight c.c.	Actual Dose c.c.	Maximum temperature	Vesicles	Result
5,571	1½	168	27	7·5	40·8	8th day	Moderate reaction. Recovery.
5,567	2	178	27	8	40·1	nil	Moderate reaction. Recovery.
5,568	6	179	54	16·1	39·2	,,	Slight reaction. Recovery.
5,569	1½	183	54	16·4	40·6	,,	Slight reaction. Recovery.
5,572	2	194	81	26·1	40·6	,,	Moderate reaction. Recovery.
5,570	2	252	81	34	40·2	10th day	Moderate reaction. Recovery.

Controls.

Hill Bull 5565. Severe attack, temperature 40·7°C. Vesicles 7th day. Bled to death. 8th day.

Hill Bull 5621. Severe attack, temperature 40·2°C. Vesicles 6th day. Bled to death. 7th day.

CONCLUSIONS.

The above results show that the mixed serum from 3 bleedings on the 8th, 12th and 16th days after injection and that from 2 bleedings on the 15th and 17th days were protective in doses of 27 c.c. for hill bulls, or 1·5 c.c. for plains bulls, per 600 lb. body weight, but the "3 bleedings" serum gave a distinctly better test.

EXPERIMENT III.

To compare the value of the mixed serum from a second series of 3 bleedings on the 8th, 12th and 16th days after the injection of virulent blood in animals previously bled three times, with the mixed serum from 2 bleedings on the 15th and 17th days in animals previously bled twice.

The advantage of injecting the rinderpest virus into an animal when in a negative phase and the detrimental effect on the potency of the serum of doing so when the animal's blood already contains a considerable quantity of antibody, were demonstrated by Holmes.[1]

Animals bled three times at the rate of 6 c.c. per 600 lb. body weight may be presumed to lose a greater amount of the rinderpest antibodies than those bled twice at the rate of 6 c.c. and 8 c.c. respectively, so that the response in antibody formation to the injection of a given quantity of antigen (virulent blood) should therefore be greater in the former than in the latter and a more potent serum be produced. The object of the present experiment was to determine whether this could be demonstrated.

The same ten hill bulls used in series A and B received an injection of virulent blood and potassium citrate solution 12 days after the last bleeding in the previous experiments. The bulls of series A were bled on the 8th, 12th and 16th days after injection at the rate of 6 c.c. per lb. body weight and the total serum obtained from the three bleedings mixed ; Serum A456. The bulls of series B were bled on the 15th and 17th days after injection as before and the total serum mixed ; Serum B34.

Serum-Making Bulls.

SUMMARY.

SERIES A.—*Second set of three bleedings at 6 c.c. per lb. body weight.*

Hill Bull No.	Virulent blood and potassium citrate injected c.c.	Bled on 8th day c.c.	Total Serum A4. c.c.	Bled on 12th day c.c.	Total Serum A5. c.c.	Bled on 16th day c.c.	Total Serum A6 c.c.
3,385	2,400	1,800	3,500	1,800	4,600	1,800	4,850
4,047	2,000	1,600		1,600		1,600	
3,925	2,000	1,600		1,500		1,500	
3,279	2,600	2,000		1,900		1,900	
4,024	1,600	1,300		1,300		1,300	
TOTAL .	10,600	8,300	3,500	8,100	4,600	8,100	4,850

[1] Holmes, J. D. E. Rinderpest. *Indian Civil Veterinary Department Memoir*, No. 3, 1911.

SERIES B.—*Second set of two bleedings at 6 c.c. and 8 c.c. per lb. respectively.*

Hill Bull No.	Virulent blood and potassium citrate injected c.c.	Bled on 15th day c.c.	Total Serum B 3. c.c.	Bled on 17th day c.c.	Total Serum B 4. c.c.
4,674	1,200	1,000		1,400	
3,851	2,200	1,800		2,500	
4,473	2,200	1,600	3,650	2,200	5,650
4,493	1,800	1,400		1,900	
4,311	1,800	1,300		2,000	
TOTAL .	9,200	7,100	3,650	10,000	5,650

Tests of Sera A456 and B34.

SUMMARY.

SERUM A456.—*The test animals in both cases and the controls were inoculated with 0·5 c.c. virulent blood from hill bull 5600, temperature 40·5° C. vesicles on 6th day.*

No. of test animal Hill Bull	Age yrs.	Weight lb.	Dose per 600 lb. weight c.c.	Actual Dose c.c.	Maximum temperature	Vesicles	Result
5,738	3	176	27	7·9	40·5	8th day	Died 14th day.
5,736	5	188	27	8·4	40·5	nil	Moderate reaction Recovery.
5,735	3	196	54	17·6	39·9	,,	Slight reaction. Recovery.
5,733	3	212	54	19	40·8	9th day	Moderate reaction. Recovery.
5,729	3	216	81	29·1	40·6	10th day	Moderate reaction. Recovery.
5,728	5	280	81	32·4	40·7	8th day	Moderate reaction. Recovery.

SERUM B34.

No. of test animal Hill Bull	Age yrs.	Weight lb.	Dose per 600 lb. weight c.c.	Actual Dose c.c.	Maximum temperature	Vesicles	Result
5,734	3	188	27	8·4	41·4	8th day	Died 11th day.
5,598	3	192	27	8·6	40·2	nil	Moderate reaction. Recovery.
5,737	3	198	54	17·8	40·8	8th day	Died 18th day.
5,730	4	206	54	18·5	39·8	nil	Moderate reaction. Recovery.
5,732	7	224	81	30·2	39·9	nil	Moderate reaction. Recovery.
5,731	2	240	81	32·4	41·0	10th day	Moderate reaction. Recovery.

Controls.

Hill Bull 5727. Acute attack, temperature 39·9°C. Vesicles 6th day. Bled out 7th day.
Hill Bull 5591. Severe attack, temperature 40·2°C. Vesicles 6th day. Bled out 6th day.

CONCLUSIONS.

Neither of the mixed sera A456 and B34 gave as good tests as the sera A123 and B12, possibly on account of greater susceptibility of the batch of hill bulls used for the tests or of greater virulence of the virus, but the three-bleedings mixed serum again proved slightly better than the two-bleedings mixed serum. The difference was however not sufficiently marked to draw any definite conclusion as to a greater production of antibodies having occurred in the animals previously bled three times than in those only bled twice.

EXPERIMENT IV.

In consequence of the foregoing results it was decided to compare the 3 bleedings and 2 bleedings systems on a large scale in the routine manufacture of anti-rinderpest serum, testing the two methods in hill bulls and buffaloes separately.

Accordingly without making any selection a proportion of the serum-making hill bulls and buffaloes were bled three times, on the 8th, 12th and 16th days after injection while the remainder were bled as previously, that is on the 15th and 17th days after injection of virus.

In this way 64 hill bulls were given three bleedings which yielded in all 162,580 c.c. of mixed serum ; Hill bull 3 bleedings serum.

One hundred and three hill bulls were bled twice and gave 220,000 c.c. of mixed serum ; Hill bull 2 bleedings serum.

Eighteen buffaloes were bled three times and gave 63,525 c.c. of mixed serum ; Buffalo 3 bleedings serum ; and 58 buffaloes bled twice gave 156,600 c.c. of mixed serum ; Buffalo 2 bleedings serum.

Each serum was then tested on 4 hill bulls—two at 27 c.c. and two at 54 c.c. per 600 lb. body weight ; the largest dose of 81 c.c. per 600 lb. was omitted in this test.

All the test animals and controls were inoculated with 0·5 c.c. of virulent blood from hill bull 5785 taken at the height of a severe attack of rinderpest ; temperature 40·3° C., vesicles 7th day.

Tests of Sera.

SUMMARY.

Serum Hill Bull 2 Bleedings.

No. of test animal Hill Bull	Age yrs.	Weight lb.	Dose per 600 lb. weight c.c.	Actual Dose c.c.	Maximum temperature	Vesicles	Result
5,830	1	174	27	7·83	40	9th day	Moderate reaction. Recovery.
5,831	3	182	27	8·19	39·8	,,	Moderate reaction. Recovery.
5,829	2	212	54	19·08	40·3	nil	Moderate reaction. Recovery.
5,828	1½	227	54	20·43	40·3	,,	Moderate reaction. Recovery.

Serum Hill Bull 3 Bleedings.

No. of test animal Hill Bull	Age yrs.	Weight lb.	Dose per 600 lb. weight c.c.	Actual Dose c.c.	Maximum temperature	Vesicles	Result
5,739	1	176	27	7·92	40·7	nil	Moderate attack. Recovery.
5,738	1½	190	27	8·55	40·6	9th day	Moderate attack. Recovery.
5,837	2	208	54	18·72	39·7	nil	Slight attack. Recovery.
5,836	2	226	54	20·34	40·5	8th day	Moderate attack. Recovery.

Serum Buffalo 2 Bleedings.

No. of test animal Hill Bull	Age yrs.	Weight lb.	Dose per 600 lb. weight c.c.	Actual Dose c.c.	Maximum temperature	Vesicles	Result
5,834	1½	196	27	8·82	40·5	9th day	Moderate attack. Recovery.
5,835	3	206	27	9·27	40·8	,,	Severe attack. Recovery.
5,832	1	197	54	17·73	40·6	nil	Slight attack. Recovery.
5,833	2	226	54	20·34	40·2	,,	Slight attack. Recovery.

Serum Buffalo 3 Bleedings.

No. of test animal Hill Bull	Age yrs.	Weight lb.	Dose per 600 lb. weight c.c.	Actual Dose c.c.	Maximum temperature	Vesicles	Result
5,827	2	192	27	8·64	40·6	nil	Slight attack. Recovery.
5,826	1	194	27	8·73	39·5	,,	Very slight attack. Recovery.
5,825	3	196	54	17·64	40·2	,,	Slight attack. Recovery.
5,824	2	206	54	18·36	40·5	,,	Slight attack. Recovery.

Controls.

Hill Bull 5840. Severe attack, temperature 40·7°C. Vesicles 7th day. Bled out 9th day.
Hill Bull 5842. Severe attack, temperature 40·8°C. Vesicles 7th day. Bled out 9th day.

CONCLUSIONS.

(1) The mixed sera obtained by both the 3 bleedings and 2 bleedings methods from hill bulls and buffaloes were protective in doses of 27 c.c. for hill bulls or 1·5 c.c. for plains animals, per 600 lb. body weight; this is less than a third of the standard dose issued.

(2) The mixed sera obtained from hill bulls by the two methods were of about equal value according to the tests.

(3) The mixed serum obtained from buffaloes by the three-bleedings method was markedly stronger than that obtained by the two-bleedings method and would probably protect in even smaller doses than 1.5 c.c. per 600 lb. body weight in plains animals.

EXPERIMENT V.

To compare the yields of serum by the 3 bleedings and 2 bleedings methods.

The observations were made at the same time as those of Experiments I to III on the 10 hill bulls of Series A and B and so cover six bleedings of the former and four bleedings of the latter series. Records were kept of the body weights of the animals throughout the experiments, the amounts of blood taken and the yields of serum at each bleeding.

The following tables show the total figures for each series of 5 animals :—

SERIES A.—*6 bleedings (2 sets of 3 bleedings at 6 c.c. per lb. each on 8th, 12th and 16th days after each injection).*

Bleeding	Rate per lb.	Total body weight	Total blood	Total fibrin	Total corpuscles	Total Serum
		lb.	c.c.	c.c.	c.c.	c.c.
1st . . .	6 c.c.	1,470	8,900	1,100	3,550	4,250
2nd . . .	„	1,455	8,800	1,150	2,700	4,950
3rd . . .	„	1,424	8,500	1,000	2,000	5,500
	Reinjec	ted with	virus.			
4th . . .	6 c.c.	1,445	8,350	1,850	3,000	3,500
5th . . .	„	1,419	8,100	1,250	2,250	4,600
6th . . .	„	1,406	8,100	1,050	2,200	4,850
	TOTAL .	8,619	50,750	7,400	15,700	27,650

SERIES B.—*4 bleedings (2 sets of 2 bleedings at 6 and 8 c.c. per lb. on 15th and 17th days after each injection).*

Bleeding	Rate per lb.	Total body weight lb.	Total blood c.c.	Total fibrin c.c.	Total corpuscles c c.	Total Serum cc.
1st . . .	6 c.c.	1,263	7,200	1,150	2,800	3,250
2nd . .	8 c.c.	1,212	10,000	1,750	3,750	4,500
		Reinjec	ted with	virus.		
3rd . . .	6 c.c.	1,279	7,200	1,000	2,550	3,650
4th . . .	8 c.c.	1,267	10,200	1,400	3,150	5,650
	TOTAL .	5,021	34,600	5,300	12,250	17,050

The following summary is obtained from a comparison of the above tables :—

——	Series A (6 bleedings)	Series B (4 bleedings)
Average total weight of hill bulls during test .	1,439 lb.	1,255 lb.
Total blood taken	50,700 c.c.	34,600 c.c.
Total serum obtained	27,650 c.c.	17,050 c.c.
Total blood taken per lb. body weight . .	35·23 c.c.	27·56 c.c.
Total yield of serum per lb. body weight . .	19·21 c.c.	13·58 c.c.
Percentage of serum from blood . . .	54·5 per cent.	49·2 per cent.
Alteration in total body weight during test .	64 lb. loss	4 lb. gain.

A comparison of the figures for the 3 bleedings and 2 bleedings methods in the above observation shows—

(1) an increased yield of serum after each injection of 2·81 c.c. per lb. body weight by the former method (9·6 c.c.) as against the latter (6·79 c.c.) ; this means a total increased yield of 41·4 per cent,

(2) an increased percentage yield of serum from the blood taken of 5·3 per cent. by three bleedings (54·5 per cent.) over that from two bleedings (49·2 per cent.) the proportion of serum increasing with each successive bleeding of a series.

The results of the above experiment were confirmed by the yields of serum obtained in Experiment IV, large series; the figures are given in the following table :—

Animal	Total number bled	No. of bleedings	Total yield of serum c.c.	Average yield per head c.c.
Hill bull	103	2	220,000	2,135
" "	64	3	162,580	2,540
Buffalo	58	2	156,600	2,700
"	18	3	63,525	3,529

In this observation the figures show an increase of serum from hill bulls of 19 per cent. and from buffaloes of 30·7 per cent. by the 3 bleedings method as compared with the 2 bleedings method, but as the weights of the animals were not recorded, this observation has not the same accuracy as the preceding one.

SUMMARY.

1. The interval allowed between the injection of the rinderpest blood and citrate solution mixture and the first bleeding for serum in hyperimmune animals may, with advantage, be reduced to 8 days, as the immune bodies are then present in full amount.

2. By taking three bleedings at the rate of 6 c.c. per lb. body weight on the 8th, 12th and 16th days after injection a mixed serum was obtained of equal (hill bulls) or increased (buffaloes) potency to that obtained by taking two bleedings 15 and 17 days after injection at the rate of 6 c.c. and 8 c.c. per lb. body weight respectively, as was done in the routine method followed at the Muktesar laboratory.

3. The actual yield of serum after each injection was increased from 6·79 c.c. per lb. body weight by the two bleedings system to 9·6 c.c. by the three bleedings system or an additional 2·81 c.c. of serum per lb. body weight; an increase of 41·4 per cent. on the former output.

With an average issue of over 500,000 c.c. of anti-rinderpest serum per month this increase without additional expenditure represents a very large reduction in the cost of manufacture.

MUKTESAR,

June 1st, 1916.

A Study in the Assimilation of Nutrients by the Rice Plant.

[*Received for publication on 9th June 1916.*]

Introduction. The growth of a plant like that of an animal is conditioned by the food-supply. There are, no doubt, other factors which limit plant production, but the question of a proper supply of the nutrient substances is a very important one in this connection.

It is of interest to note that the assimilation of any particular element, *e.g.*, potassium, does not go on at an uniform rate but varies at different periods of the plant's growth, being sometimes more rapid than at others. It follows that if, during the period when the plant's demand for the particular nutrient substance is very great, there is available an abundant supply of it, the plant response, or yield, will be great. On the other hand, the yield will be comparatively low if there is a lack of the element at this critical period. In order, therefore, to ensure a maximum crop it is important to know the food-requirements of the plant in question.

On account of the great economic importance of the rice crop, a study was made of the assimilation of the nutrient materials by this plant at various stages of growth.

In Hawaii, Kelley and Thompson have investigated the composition of the rice plant at different stages of its growth.[1] Work on similar lines has also been done in Spain.[2] An account of this is given in the course of a very interesting paper on the cultivation of rice in Spain and the International Rice Congress at Valencia.[3] The ash composition of upland rice at various stages of growth has been studied at Porto Rico.[4]

It seemed desirable, however, to study this question under Indian conditions.

Soil. In such a work successive samples of plants at different stages of growth have to be taken out from the field and examined, and it is essential that the growth should be uniform over the whole area under observation.

A piece of land in the Sabour Farm (about one-tenth of an acre in area) was taken. Results of previous crops of rice indicated that the plot was quite uniform throughout. The soil is a non-calcareous rice land clay (*kewál*).

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[1] *Hawaii Agri. Exp. Sta., Bull.*, 21.

[2] Herrero-Egaña "Marche de l'Absortion des principes fertilisants par le riz", *Actes du Congrès International de Riziculture, Valencia*, 1914, p. 128.

[3] E. J. Butler, *Agricultural Journal of India*, ix (1914), p. 326.

[4] Gile and Carrero, *Jour. Agri. Research* v (1915), p. 357.

The chemical composition of the soil is given below :—

	Per cent.
Organic matter and combined water	2·19
Carbonic acid	0·11
Lime	0·99
Nitrogen	0·08
Phosphoric acid	0·11
Potash	1·11
Available phosphoric acid	0·004
Do. potash	0·021

Seed. For the purpose of obtaining an uniform crop the advantages of the use of seed obtained by pure line culture are obvious. The seed selected was " Kalamdan " which has for a number of years been regularly grown at Sabour and is at present the standard medium *áman* paddy of the Sabour Farm. It was originally derived from pure culture and its purity was maintained, as far as is possible under field conditions, by " rogueing " every year.

Cultivation, *etc*. When the harvest of the previous year's rice crop was over, the land was ploughed up with a Punjab plough. In the first week of May, it was cross-ploughed with the country plough A fortnight later ploughing and corner-ploughing were again done.

In order to do away with the disturbing factors consequent on transplanting, it was decided to allow the rice to grow to maturity in the same field where it was sown. The seeds were sown on May 21st by dibbling in plough furrows and afterwards covering them up by beaming. Weeding was done once in each of the months of June, July and August and twice in September.

The plot was irrigated only once in August.

Regarding the character of the season, as affecting the *áman* paddy crop of the year, it may be noted that the rainfall was fairly good in total amount and well-distributed over the season, except in June and August when it was less than the normal. With more rainfall in June the plants would have got a better initial start and irrigation could have been dispensed with if the August rainfall were more copious.

Sampling. A number of plants (varying, according to the size of the plants, from 230 to 10) were selected from different parts of the field to make the samples fairly representative of the whole plot. They were carefully dug out with as much soil adhering to the roots as was practicable. The soil, when necessary, was carefully watered previous to the uprooting of plants, but in spite of this and other precautions adopted, the roots of the later samples suffered some damage on account of hardness of clods formed round them. Possibly some fine rootlets were lost in most cases but the losses in the earlier samples were negligible as compared with those in the later ones.

The soil adhering to the roots of the plants collected was carefully washed out and the samples taken to the laboratory.

The plants were then divided into their botanical parts. "Roots" were separated first. As in actual practice some stubble is left attached to the roots, the separation was made a little higher up the culm (*i.e.*, near about the place where a change of colour from whitish to the green of the stem began).

Except in case of the first lot of samples the culms of which had not yet developed into true stalks, the vegetative portion was then sub-divided into leaves, stems, and, where the inflorescence had appeared, ears. The leaves were separated in such a way that the leaf sheath remained on the stem. In case of the samples where the ears had filled with starch, the ears were further sub-divided into grain and chaff (including ear stalks and the axis). The components were then dried, weighed and analysed.

The first sample was that of very young seedlings and was taken on June 30th.

The next sample was taken on July 22nd when the seedlings had attained the transplantation stage.

Adult plants in their preflowering stage were collected on August 21st.

On October 27th two samples were taken, when the plants had begun to flower. In one set the grain was in the "water" stage. In the other, it was beginning to form "milk."

The next sample was taken on November 29th when the plants were ripe for harvest.

The plants were allowed to remain in the field till they attained the dead-ripe stage when the last sample was taken on January 7th, 1916 Unfortunately, however, there was considerable loss of grain due to shedding and depredations of rats.

Total dry matter formed. The following table shows the amounts of dry matter at different stages of growth :—

TABLE I.

Average weight in grammes per plant (dry matter).

No.	Stage	Days after sowing	Root	Stem	Leaf	Stem and leaf	Chaff	Grain	Ears	Above ground	TOTAL.	Ratio under-ground
I	Seedling (very young)	40	0·077	..	..	0·180	..	..	..	0·180	0·257	0·42
II	Do. (transplantation.)	62	1·160	1·317	0·849	2·166	..	..	..	2·166	3·326	0·5
III	Preflowering . .	92	2·051	1·771	1·304	3·075	..	..	..	3·075	5·126	0·6
IV	Flowering ("Water")	159	7·484	20·593	9·816	30·409	..	..	7·523	37·932	45·416	0·1
	Do. ("milk").	159	7·811	17·266	8·401	25·667	..	..	12·701	38·368	46·179	0·2
V	Ripe . . .	192	9·556	24·867	8·100	32·967	6·369	12·736	19·105	52·072	61·628	0·18

It has been observed that after the flowers begin to appear the formation of roots goes on less actively. This coincides, however, with a rapid accumulation of dry matter in the above-ground parts of the plant which continues till its maturity. During the flowering stage as "milk" forms in the grain, there occurs a translocation of the dry matter from stem and leaves into the flowers.

Composition of the samples. Table II shows the composition of the component parts of the plant at different stages of growth, calculated on the dry basis.

It would be interesting to find out also the *amounts* of the plant-foods taken up by the above-ground part and by the entire plant (see Table III).

As already pointed out some of the fine roots were doubtless lost,

TABLE II.

Composition of the different parts of the rice plant (calculated on a dry basis).

No.	Stage	Days after sowing	Parts	Per cent.			Milligrams per plant		
				Total Nitrogen	Phosphoric acid	Potash	Total Nitrogen	Phosphoric acid	Potash
I	Seedling (very young) .	40	Root . .	2·14	0·37	1·85	(1·65	0·29	1·42)
	Do. .		Stem and leaf .	3·48	0·40	1·91	6·26	0·72	3·44
II	Seedling (transplantation)	62	Root . .	1·02	0·25	1·91	(11·83	2·90	22·16)
	Do. .		Stem . .	0·77	0·26	2·99	10·14	3·42	39·38
	Do. .		Leaf . .	2·11	0·27	2·16	18·86	2·29	18·34
III	Preflowering . .	92	Root . .	0·74	0·25	1·17	(15·18	5·13	24·00)
	Do. .		Stem . .	0·79	0·21	3·43	13·99	3·72	60·75
	Do. .		Leaf . .	1·44	0·22	2·73	18·78	2·88	35·60
IV	Flowering ("water") .	159	Root . .	0·52	0·20	0·80	(38·91	14·97	59·86)
	Do. .		Stem . .	0·83	0·38	2·43	170·92	78·25	500·41
	Do. .		Leaf . .	1·94	0·38	1·48	190·43	37·30	145·27
	Do. .		Ear . .	1·16	0·40	0·63	87·27	30·09	47·39
	Flowering ("milk") .	159	Root . .	0·45	0·18	1·02	(35·15	14·06	79·67)
	Do. .		Stem . .	0·69	0·28	2·96	119·14	48·34	511·08
	Do. .		Leaf . .	1·65	0·25	1·19	138·62	21·00	99·97
	Do. .		Ear . .	1·04	0·45	0·64	132·09	57·15	81·28
V	Ripe	192	Root . .	0·61	0·15	0·66	(58·29	14·33	63·07)
	Do.		Stem . .	0·53	0·13	2·34	131·79	32·32	581·89
	Do.		Leaf . .	0·54	0·09	0·57	43·74	7·29	46·17
	Do.		Grain . .	1·62	0·68	0·33	206·32	86·60	42·03
	Do. . . .		Chaff . .	0·52	0·16	0·52	33·12	10·19	33·12
VI	Dead ripe . . .	230	Root . .	0·72	0·15	0·51			
	Do. . . .		Stem . .	0·56	0·11	1·48			
	Do. . . .		Leaf . .	0·77	0·14	0·67			
	Do. . . .		Grain . .	1·58	0·57	0·25			
	Do. . . .		Chaff . .	0·63	0·20	0·53			

The figures within brackets are approximate (as it cannot be assured that all the roots of the plants had been collected).

TABLE III.

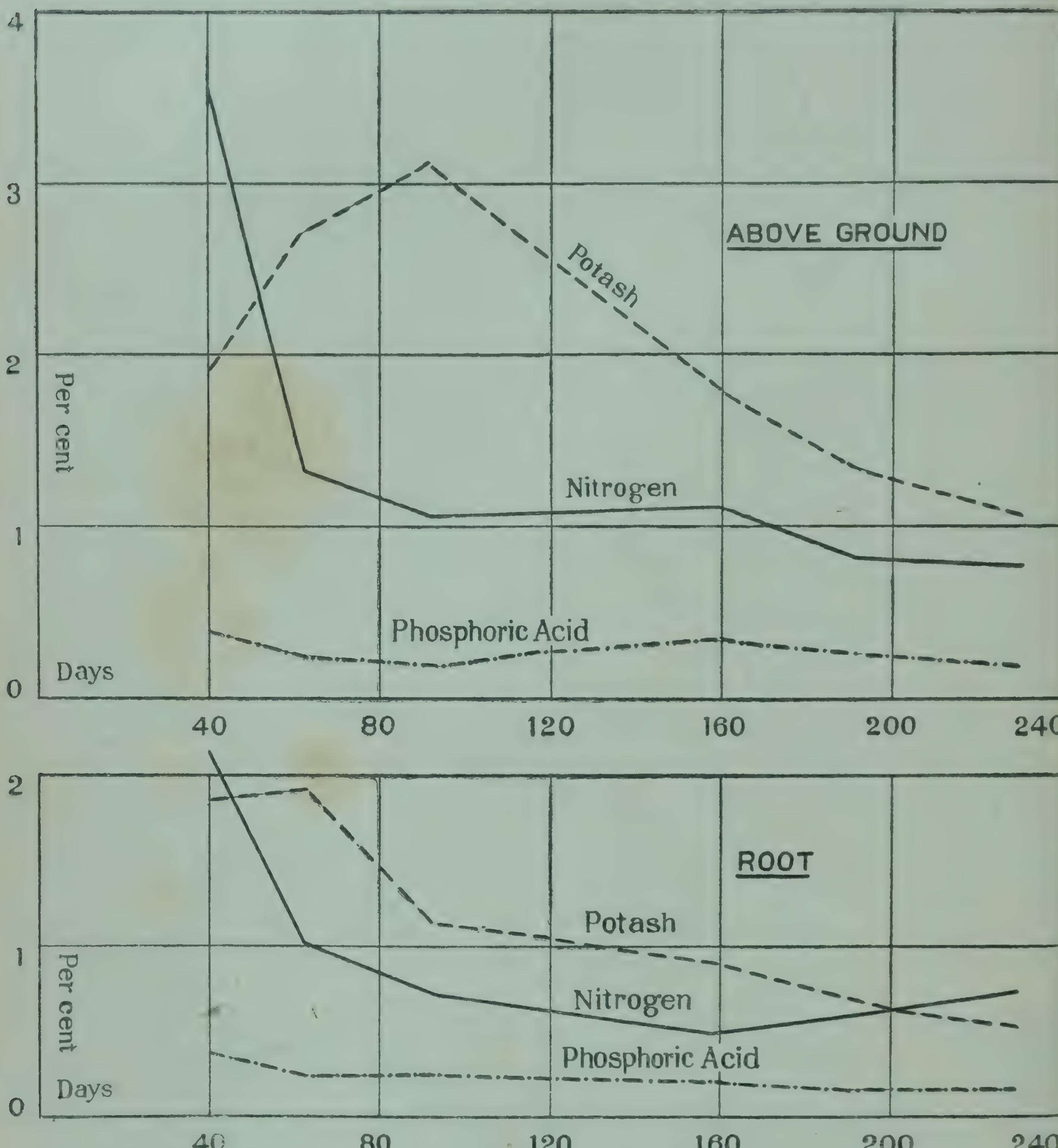
Composition of the roots and above-ground parts of the rice plant (calculated on a dry basis).

No.	Stage	Days after sowing	Parts	Per cent			Milligrams per plant		
				Nitrogen	Phosphoric acid	Potash	Nitrogen	Phosphoric acid	Potash
I	Seedling (very young) .	40	Root . .	2·14	0·37	1·85	(1·65	0·29	1·42)
	Do. .		Above ground .	3·48	0·40	1·91	6·26	0·72	3·44
	Do. .		(Total .	3·08	0·39	1·89	7·91	1·01	4·86)
II	Seedling (transplantation)	62	Root . .	1·02	0·25	1·91	(11·83	2·90	22·16)
	Do. .		Above ground .	1·34	0·26	2·67	29·00	5·72	57·72
	Do. .		(Total .	1·23	0·26	2·40	40·83	8·62	79·88)
III	Preflowering . .	92	Root . .	0·74	0·25	1·17	(15·18	5·13	24·00)
	Do. .		Above ground .	1·07	0·22	3·13	32·77	6·60	96·35
	Do. .		(Total .	0·94	0·23	2·35	47·95	11·73	120·35)
IV	Flowering ("water") .	159	Root . .	0·52	0·20	0·80	(38·92	14·97	59·87)
	Do. .		Above ground .	1·18	0·38	1·83	448·62	145·64	693·07
	Do. .		(Total .	1·07	0·35	1·66	487·54	160·61	752·94)
	Flowering ("milk") .	159	Root . .	0·45	0·18	1·02	(35·15	14·06	79·67)
	Do. .		Above ground .	1·03	0·33	1·80	389·85	126·49	692·33
	Do. .		(Total .	0·92	0·30	1·67	425·00	140·55	772·00)
V	Ripe	192	Root . .	0·61	0·15	0·66	(58·29	14·33	63·07)
	Do.		Above ground .	0·80	0·26	1·35	414·97	136·40	703·21
	Do.		(Total .	0·77	0·25	1·24	473·26	150·73	766·28)

The figures in brackets are approximate (as it cannot be assured that all the roots of the plants had been collected).

especially those of the later samples. The composition of the total plant (*i.e.*, including roots) cannot therefore be determined accurately. Neglecting this loss, the figures given in Tables II and III are obtained. For convenience of comparison the analyses of the roots have again been shown in Table III. The figures in both the tables refer to the composition of the dry matter.

Nitrogen. During the very young seedling stage the roots contain 2 per cent. nitrogen which rapidly falls to 1 per cent., then gradually diminishes to three-quarters of one per cent. ultimately coming down to half a per cent. at which figure it remains practically constant.


ABOVE GROUND
Potash
Nitrogen
Phosphoric Acid
Per cent
Days
0
1
2
3
4
40
80
120
160
200
240
ROOT
Potash
Nitrogen
Phosphoric Acid
Per cent
Days
0
1
2
40
80
120
160
200
240

The above-ground parts are always richer than the roots in their nitrogen content. Here again, as in the roots, the percentage on the whole diminishes as the plant advances in age. The fall is rapid between the first and the second stage and then becomes more gradual. The nitrogen content is practically constant between the preflowering and the flowering stages and falls afterwards, with a slight rise at the last stages. The variation in the nitrogen content of the above-ground parts is thus analogous to that of the roots.

At the earlier stages the leaves are practically twice as rich in nitrogen as the stems. As the ears form, both the leaves and the stems lose nitrogen ; and by the time that the grains " fill up " the former retain only about half a per cent. of nitrogen. At this stage the nitrogen accumulates most in the grain (1·6 per cent), the roots, stems, leaves and " chaff " containing practically the same percentage of nitrogen (0·5 per cent). It seems, therefore, that there is a tendency for the nitrogenous matter to press forward towards the top of the plant where the grains are.

Phosphoric acid. The percentages of phosphoric acid in the roots fall as the plant advances in age.

In the above-ground parts it suffers a fall during the earlier stages but rises when the grains fill up. Afterwards it falls again.

Till about the time that flowers appear the roots and the above-ground parts are about equally rich in phosphoric acid. With the emergence of the panicle, the phosphoric acid accumulates more in the above-ground parts than in the roots.

As the ears mature there is an accumulation of phosphoric acid in the grain. At the same time the roots, stems, leaves and " chaff " become poorer, all ultimately containing about the same percentage. Speaking generally, the analytical figures seem to indicate that available phosphates in the soil were low right through the life of the plant.

Potash. The percentages of potash are the same in the roots in the first and second stages but become considerably lower after the second stage. The fall is maintained, though at a slower rate, till the last.

The percentage of potash in the above-ground parts reaches its maximum not in the first stage but in the third, after which it gradually decreases.

The nitrogen, phosphoric acid and potash contents of the plant at various stages of growth are shown in the accompanying chart.

Loss undergone by the soil. The plants were harvested in the dead ripe condition as it was intended to see what variation in composition they underwent after they had reached the ripe (harvesting) stage. There was, however, some loss of grain due to the lodging of the plants and to depredations by rats.

The yield of the crop was $10\frac{1}{2}$ maunds per acre. In a contiguous plot, where the crop was harvested at the proper time,* the yield of the same variety of paddy in the same season, was 12 maunds per acre.

Assuming the average of yield of dry grain under the conditions of the Sabour Farm to be about 900 lb. per acre, it is possible to ascertain by calculation the amounts of the chief constituents the plants require to yield this crop. It is seen that, neglecting the amounts absorbed by the stubble and the roots, such a crop removes 29·33 lb. nitrogen, 9·64 lb. phosphoric acid and 49·69 lb. potash from the soil.

Comparison with data obtained by previous workers. It would be interesting to compare the figures obtained in the course of the present investigation with those got by Kelley and Thompson from the "check plat" (*i.e.*, not treated with manure) at Hawaii. In the course of a year they had grown two crops of rice, *viz.*, a "spring crop" (January to May; the average temperature being 72°F.) and a "fall crop" (June to October; average temperature being 77°F.). This latter one only, however, bears some comparison with the crop grown here.

In comparing the figures it has to be remembered that the climatic and soil conditions are not the same in the two places and that the development of the rice at Hawaii was more rapid; it took only 95 days from the time of transplanting to that of harvesting. In other words it had about 120 days' growth in all against 192 days' growth here to reach the harvest stage. An attempt is, however, made below to compare the specimens of such stages of development of rice at Hawaii as nearly correspond to the samples collected here.

The first harvest at Hawaii was taken "just before the formation of the flower." This would correspond to the sample taken at Sabour during the third ("preflowering") stage. At Hawaii, the potash in the roots is twice as much, and, in the above-ground parts, the same as at Sabour. Nitrogen is much higher in the Hawaii samples, while the phosphoric acid is more than four times as much as here.

The second Hawaiian harvest was "at the time of full flower." The agreement as to the nitrogen content of the various parts with those obtained here during the fourth ("flowering") stage is close. Percentages of potash in the roots, ears and the total plant also agree. The leaves of the Hawaiian samples were however richer and the stems poorer than those of the Indian samples. The phosphoric acid is again higher in the Hawaii samples, the panicles however not differing much in their content of phosphoric acid; on the other hand, the roots at Hawaii are five times richer.

At maturity, in the samples at Hawaii, there were practically the same percentages of nitrogen (except in the grains) and of potash (in

*The paddy in this plot was transplanted and not broadcasted.

all the parts except the leaves and the chaff) as in the samples here. The grains at Hawaii were poorer in nitrogen and the leaves and chaff, richer in potash. The amount of phosphoric acid in all the parts of the plant at Hawaii were higher although the difference in the samples at this stage (except the roots) is not so great as in the specimens from the earlier stages of growth. At maturity the roots are about eight times as rich as here.

It is thus seen that the agreement in the analyses of the Hawaiian and the Indian samples is fairly close except with regard to phosphoric acid. The latter is always less in the specimens examined at Sabour.

It may not be out of place to mention here the well-established fact that environment exercises a considerable influence on the composition of mature plants.

The discrepancy in the amounts of phosphoric acid may be due to one or more of the following causes, *viz.*, difference in the varieties of the rices, variations in the agricultural conditions and difference in the nature of the soils. The Hawaii soil is much richer than the Sabour soil, as will be apparent on comparing their composition as given below :—

	Hawaii soil	Sabour soil
	Per cent.	Per cent.
Organic matter	10·11	2·19*
Lime	1·60	0·99
Phosphoric acid	0·48	0·11
Potash	0·35	1·11
Nitrogen	0·25	0·08

* This includes also the combined water.

It is intended to study what the composition of rice plant is when it is well supplied with available plant food, specially phosphoric acid.

It may also be mentioned here that, from observation of crops growing in pots filled with different Burma soils, Warth has come to the conclusion "that the soil texture exerts a more marked effect upon the yield (of paddy) than the soil reaction or the presence of larger or smaller amounts of plant food."[1]

Turning to the figures obtained by Giles and Carrero at Porto Rico, it is instructive to note that they found that the percentage of nitrogen in the dry matter of the whole plant above ground decreased with the

[1] Warth, F. J. Note on the soil of the Experimental Farms, *Dep. Agri., Burma, Bull.* no. 13 of 1916, p. 5.

age, and that the mature plant above ground, at 123 days with the seeds ripe, contained an equal amount of phosphoric acid and slightly more nitrogen and considerably more potash as compared with plants of 103 days with the panicles just out. With the exception of the fact that in the present experiments the potash did not appreciably increase after the appearance of the ears, the results at Porto Rico generally agree with those obtained here.

GENERAL CONCLUSIONS.

It is seen that during the earlier periods of growth all plant organs are considerably richer in nitrogen, phosphoric acid and potash than in the later periods, and that the amounts of these substances as a rule gradually diminish, only increasing under certain conditions, as in the newly-formed organs—the seeds.

In fact, by the time the plants flower, practically all the nitrogen, phosphoric acid and potash are taken up. After this the energies of the plant get more concerned with the formation of carbohydrates and the translocation of the elements already absorbed. After finally depositing the reserve material in the seed, the plant dies. Of course, the foregoing processes do not strictly follow upon one another, but they operate rather somewhat simultaneously.

These agree with the results obtained by Wilfarth, Römer and Wimmer.[1]

These authors also found that wheat and barley plants contained very considerably less potash and nitrogen at maturity than previously. They are of opinion that these elements, after assisting in the performance of the physiological processes within the plants, return again to the soil through the roots. Le Clerc and Breazeale [2] were unable to find such a downward transmigration within the plant, but found that rain and dew are capable of leaching out a part of the elements.

In the present experiments, the plants, in the course of their maturity, were not found to sustain any loss of nitrogen and potash, while the roots were found to get steadily poorer in nitrogen, phosphoric acid and potash thus proving the absence of a backward translocation. The present data therefore confirm those obtained by Kelley and Thompson (*loc. cit.*).

On account of the fact that practically all the nitrogen, phosphoric acid and potash are absorbed by the plant in the early stages of its growth, it is essential that the manure applied to the field should be such as would readily provide plant-food available for absorption during

[1] *On the assimilation of the elements of nutrition by plants during different periods of their growth,* trans. Emslie, pp. 25 et seq.

[2] *U. S. A. Dept. Agri. Yearbook,* 1908, p. 389.

these stages. Later on, manures might be of indirect advantage, but after the formation of the ears, the amounts of plant-food materials taken up would be negligible. Thus, a practical farmer, who aims at securing the maximum possible yield, should see that there is enough of readily available plant-food in the soil during the early stages of the growth of the plant.

It has to be remembered that although practically there is a cessation of absorption of nutrients by the roots at this stage, the materials absorbed have yet to pass on to the grain, and a large amount of carbohydrates has to get synthesized. It is thus a very critical period in the life of the rice plant, and a moderate fall of rain (*háthiá* rain) or a change of water (*nigár*) is essential at this time for the production of a good crop. At the later stages of growth, proper aeration of the roots is of special importance inasmuch as it fosters the respiratory functions and thus hastens the translocation of food materials on to the grain. It is well known that rice can effectively take up oxygen only from the amounts dissolved in water and not from gaseous mixtures.[1] Mr. and Mrs. Howard are of opinion that the chief value of the *háthiá* rains might be to give the roots a final aeration.[2] It is intended to make some experiments in this connection.

Feeding value. The nutritive constituents of the various parts of the rice plant, at the different stages of its growth, have been determined and the results are recorded in Table IV, calculated on a dry basis.

TABLE IV.

Feeding value of the different parts of the rice plant (*calculated on a dry basis*).

No.	Stage	Part of the plant	Ether extract	Crude protein	Soluble carbo-hydrates	Crude fibre	Soluble mineral matter	Sand	Food units
I	Seedling (very young) .	Stem & leaf	4·62	21·75	40·53	19·28	4·95	8·87	106·5
II	Do. (transplantation)	Stem	1·29	4·50	55·61	23·56	6·75	8·29	70·1
	Do. Do. .	Leaf	3·87	8·63	52·09	19·49	6·07	9·85	83·3
III	Preflowering . .	Stem	1·61	6·19	53·89	24·92	7·47	5·92	75·9
	Do. . .	Leaf	5·09	11·44	48·26	20·64	6·17	8·40	89·6
IV	Flowering (" water ") .	Stem	1·51	5·19	48·71	26·47	5·55	12·57	65·5
	Do. .	Leaf	4·54	12·12	47·72	20·69	3·94	10·99	89·4
	Do. .	Ear	1·54	7·25	48·96	30·38	1·70	10·17	70·9
	Flowering (" milk ") .	Stem	1·20	4·31	47·00	28·74	6·44	12·31	60·8
	Do. .	Leaf	5·04	10·31	50·83	18·31	4·11	11·40	89·2
	Do. .	Ear	2·00	6·50	58·03	23·47	1·87	8·13	79·3
V	Ripe	Stem	0·90	3·31	42·66	34·18	1·74	17·21	53·2
	Do.	Leaf	3·51	3·38	46·22	26·54	3·70	16·65	63·4
	Do.	Grain	2·91	10·13	84·70	0·62	1·49	0·15	117·2
	Do.	Chaff	0·90	3·25	40·18	35·62	1·42	18·63	50·6
VI	Dead ripe . . .	Stem	1·02	3·50	44·69	32·43	4·35	14·01	56·0
	Do. . . .	Leaf	2·48	4·81	46·86	23·52	5·25	17·08	65·1
	Do. . . .	Grain	2·68	9·88	85·37	0·70	1·22	0·15	116·8
	Do. . . .	Chaff	1·00	3·94	43·99	32·48	2·86	15·73	56·3

[1] Harrison and Aiyer, Gases of swamp rice soils, parts I and II. *Mem. Dep. Agri. Ind., Chem. Series*, vol. iii, no. 3 and vol. iv, no. 1.

[2] Soil Ventilation, p. 22 and Soil erosion and surface drainage, pp. 2 and 12. *Bulls. 52 and 53, Agri. Res. Inst., Pusa.*

The ether extract contains, besides oil, a considerable extent of wax, colouring matter and other substances. The figures for crude protein are obtained by multiplying the percentages of total nitrogen by 6·25. Other nitrogenous substances like amides and amino acids are therefore also included in the crude proteins. The figures for soluble carbohydrates are obtained by subtracting from 100, the amounts of ether extract, crude protein, crude fibre and ash.

The last column gives the "food-units," which serve as a convenient basis for comparison. In calculating these only the ether extract, crude protein and soluble carbohydrates have been taken into account. The other constituents have been neglected. No doubt the mineral substances play an important part in the physiological processes going on in the animal body but they have no value as direct sources of energy. Moreover no method of measuring their value is known. As to the crude fibre, it is mostly indigestible and the fraction which is digestible requires the expenditure of a relatively large amount of energy to assimilate it. The ether extract and crude protein have been classed together and taken to be about two and a half times as useful as the soluble carbohydrates.

An examination of the table will show that the straw declines in value with the age of the plant. The leaves are more nutritious than the stems of the same period, containing as the former do more oil and protein and slightly more carbohydrates (and also less fibre). The leaves in the preflowering and the flowering stages are about equally nutritious but decline considerably in value as the plant matures. The "chaff" is about equal to the stems in nutritive constituents. Dead ripe plants are not inferior to the ripe samples if not slightly better.

SUMMARY.

1. The total dry matter in a rice plant increases up to the time of maturity, the largest increase in the weight of the crop occurring however before the formation of the flowers.

2. The percentage of nitrogen generally exhibits a steady and continuous decrease from the first to the last period of growth, the most rapid decline being noted in the second period. In the roots there is a very slight rise during the last stages.

3. Phosphoric acid content of the above-ground parts remains practically the same except in the first stage and during the flowering stage when it is slightly higher. In the roots, there is a slight but regular decline maintained through all the stages.

4. The percentage of potash in the above-ground parts increases from the first stage to the preflowering stage from whence forward there

is again a decline. In the roots it is the same in the first two stages after which there is a continued fall.

5. As the ears form and mature there occurs a concentration of nitrogen, phosphoric acid and potash in the grains at the expense of the other parts of the plant.

6. The assimilation of nitrogen, phosphoric acid and potash by the plant is fairly complete by the time flowers appear. Hence enough plant-foods must be available for the plant during the early stages.

7. There does not happen any migration of the absorbed nitrogen and potash back into the soil.

8. When there is a yield of 900 lb. dry grain, the soil suffers a depletion of 29·33 lb. nitrogen, 9·64 lb. phosphoric acid and 49·69 lb. potash per acre by the removal of the grains and straw.

9. The feeding values of the parts of the rice plant at different stages of growth have been determined.

Pusa,

June, 1916.

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I. Introduction.

AS far as it is known Berseem (*Trifolium alexandrinum*) was first introduced and grown in India by Mr. Fletcher, then Deputy Director of Agriculture, Bombay, at the Government farm, Mirpur Khas, Sind, in 1904. Two varieties were tried—Fahli and Miscawi. The results were not very promising during the next three seasons though one plot yielded seed at the rate of 182 lb. per acre.

The writer on taking charge of the Mirpur Khas farm in 1907 was struck with the similarity of the surrounding country to the low salt country in the extreme north of Egypt. Seed was obtained from the north of Egypt with difficulty and nothing else was thereafter used. It is worth noting that the 'fellah' in Garbia and Behera looks on any seed from Upper Egypt with the greatest suspicion. The Fahli or Saidi seed is considered by him as an adulterant, pure and simple. He will buy nothing if he can help it but 'belladi' or local seed produced in the North. It is most difficult to buy berseem seed as a rule. It must be bought in small parcels in the village 'souks' or markets and it is nearly always dirty. Samples generally contain a proportion of chicory seed and 'senji' seed (*Melilotus parviflora*) besides sand and dirt and frequently dodder. The price fluctuates in an extraordinary degree. It may be anything up to £2-£3 per ardeb, say four maunds.

This question of the origin of berseem seed is undoubtedly important and especially large, plump, highly coloured seed which has probably come from Upper Egypt should be avoided. The names often given as Miscawi, Fahl, Khadrawi, Baali are of little importance. Miscawi or Belladi from the north coast is the only kind of seed which should be obtained for India.

The rôle that berseem plays in the agricultural economy of Egypt is very great, in lower Egypt alone out of a cultivated area of 3 million acres nearly 1 million acres berseem are sown each year. Without this crop it would not be possible to maintain the constant succession of crops under the great drain of perennial irrigation in the richest agricultural country of the world.

Berseem is a cold weather rotation crop and it may be said to feed the whole of the livestock of Egypt from November to June. Among the 'fellaheen' the cattle, horses, camels, goats and sheep get absolutely no other feeding. Usually the stock is tethered in the crop, and this method gives the best results except in cold wet weather which sometimes occurs in December and January.

II. Berseem in Egypt.

In Egypt the seed is generally sown in September and October, though on fallow land if water is available it does very well sown in August. The young plants will not stand great heat especially if there is not an abundant supply of irrigation water. On the other hand, late sown berseem will suffer from cold in December if it has not been well started in growth. A common rotation in the north of Egypt is cotton followed by berseem in the first year, after several cuttings the latter is cut finally for seed in May of the second year, this is followed by maize or *jowar* which is again followed by berseem which is ploughed in in March before cotton. It is often sown among standing cotton before the last picking. A heavy watering is given and the seed is broadcasted in the standing water which should be at least 2″ deep, at the rate of $2\frac{1}{2}$ 'kelahs' to the 'feddan' or say 60 lb. to the acre. On new land in North Egypt much trouble is experienced by water stagnating in hollow places. This is fatal to the young plants. No trouble was experienced in Sind in this respect. On the other hand, the young plants must not be allowed to get too dry.

When berseem is sown among standing cotton, it, when ready for the first cutting, is cut down with the cotton stalks. This is a cheap method of sowing, it is economical of labour and irrigation water and the stalks give shade to the young plants if the weather is too hot. The disadvantage is that the soil among the cotton is tough and hard on the top and this would be better broken before sowing.

After maize or millet there is plenty of time to plough the land. This always gives the best results, as the soil is more absorbent and the young seed sinks into a damp firm seed bed.

If the land is level half acre plots are flooded and sown at once, but frequently smaller plots are sown. The seed is always soaked in water for 12-24 hours before sowing.

In 2-3 months after sowing the crop will be ready for the first cutting. It should be over 1 foot high with a few white flower heads showing. The number of waterings required varies immensely according to the soil. For the first month the young 'braird' requires careful watching especially on saltish land. Afterwards it is quite hardy. The 'fellaheen' consider it good practice to cut and carry the first cutting as the plants are supposed to tiller better. The cattle are tied along a neighbouring bund and a small girl is supposed to be able to cut and carry as much fodder as a pair of cattle will eat. After cutting the berseem receives a good flooding; if possible the irrigation water is allowed to run off the plots at one end while it runs in at the other. Thereafter the plot should give a cutting once a month till it is dried out by the hot winds in early summer.

The succeeding cuttings are taken by tethering cattle in the crop. They are tied to pegs and moved forward as required. An acre should keep 100 bullocks for a day. The cutting requires careful supervision, the object is to get an uniform cut over the whole plot so that the next lot will sprout as evenly as possible. Sheep often follow the cattle to finish off.

When the crop is being kept for seed it should not be cut or grazed after March. £3 per acre per cut is not an unusual price to obtain in Egypt. As to fodder, Bolland, the Egyptian Government Botanist, gives the following yields per acre for 1 cut.

Fahl . . .	27,132 rottles (Upper Egypt basin land, it only gives 2 cuts).
Miscawi . . .	19,026 rottles.
Baali . . .	12,726 rottles.
Khadrawi . .	15,120 rottles.

NOTE.—1 rottle = ·99 (lb.).

These yields are probably from 1st class land in middle Egypt. In the North 4-5 tons per acre would be a good crop.

About 200 lb. of seed per acre would not be considered a bad yield on "3 Kantar" cotton land, *i.e.*, land which produces 300 lb. of ginned cotton per acre.

III. Cultivation Figures in Sind.

Sukker Government Farm, Sind	Area	Year	Sown after Jowar on the
Plot B 5 . .	1 Acre	1914-15	24th October 1914.

This was sown rather late, but it is usually too hot to sow berseem in North Sind till the beginning of November. As it was after *jowar* the land was not ready before. In all including the preparation of the land 17 waterings were given. The land is stiff salt alluvium.

Yields of above acre plot.

	Date	Estimated yield	Value	Remarks
			Rs.	
1st cutting .	23rd December 1914 . . .	60 maunds of 80 lb.	14	Fed to bullocks.
2nd cutting .	21st February 1915	80 ,, ,,	15	Sold.
3rd cutting .	25th March 1915	100 ,, ,,	22	Sold.
4th cutting .	21st April 1915	80 ,, ,,	19	Fed to bullocks.

The plot was ploughed in for cotton on the 23rd of April, else another cutting could have been obtained. 40 lb. seed was sown per acre.

SUKKER GOVERNMENT FARM.

Two plots cut and threshed for seed.

	Area	Year	Sown after Sugdasi Paddy
Plot D 1 . .	1 acre	1913-14	14th November 1913.

	Date	Estimated yield	Value	Remarks
			Rs. A. P.	
1st cutting .	15th January 1914	85 maunds	20 8 0	Sold.
2nd cutting .	12th March 1914	60 ,,	13 8 0	Fed to bullocks.
3rd cutting .	1st June 1914	140 lb. seed		

FIELD AT SÚKKER.

FIELD SOLD TO LOCAL "GHARRYWALLAS."

	Area	Year	After paddy
Plot D 2 . .	1 acre	1913-14	18th November 1913.

	Date	Estimated yields	Value	Remarks
			Rs. A. P.	
1st cutting .	20th January 1914	65 maunds	15 4 0	Sold.
2nd cutting .	16th March 1914	83 ,,	20 0 0	Fed.
3rd cutting .	1st June 1914	220 lb. seed		

Mirpur Khas Government Farm.

	Area	Year	Sown after Bajra	Remarks
Plot F 1 .	¾ acre	1913-14	15th November 1913.	30 lb. seed sown.

9 irrigations	Date	Yields	Value per acre
			Rs. A. P.
1st cutting . .	29th December 1913	4,800 lb. per acre	18 12 0
2nd cutting . .	19th January 1914	6,933 ,, ,, ,,	27 1 4
3rd cutting. . .	27th February 1914	3,200 ,, ,, ,,	12 8 0

Cut for seed 24th May 1914, estimated yields per acre, 1½ maunds.

Mirpur Khas Government Farm.

	Area	Year	Sown after Jowar	Remarks
Plot D 1 .	$\frac{38}{40}$th acre	1914-15	18th October 1914	Resown 31st October 1914.

	Date	Yields
1st cutting	27th December 1914	4,000 lb. per plot.
2nd cutting	5th February 1915	4,800 " " "
3rd cutting	12th March 1915	5,200 " " "
4th cutting	12th April 1915	3,600 " " "
5th cutting	30th April 1915	1,600 " " "

The plot was then ploughed in for cotton.

The cost of seed in Sind in an average year is Rs. 16 per maund of 80 lb., this includes all freight charges, etc.

IV. Cultivation.

The seed should be steeped for 24 hours before sowing. It is best sown in ploughed land which has been irrigated to a depth of 2″-3″.

The time for sowing is at the change between the hot and beginning of the cold seasons. 30-35 lb. seed per acre can be sown.

It can be sown in standing cotton or in wet paddy provided that in the latter case the water will not remain stagnant too long.

The amount of water required and the number of irrigations will be a matter for local conditions to settle. In a hot dry country like Sind when the hot weather lasts till end of November many irrigations are required especially when the land is alkaline.

ROOT OF BERSEEM 5 MONTHS FROM SOWING, SHOWING NODULES CONTAINING NITROGEN-FIXING BACTERIA.

It has been estimated that a good crop of berseem returns 300 lb. of available nitrogen to the soil per acre, as by the end of the season the roots are covered by nodules containing nitrogen-fixing bacteria. This is of course only when the crop is eaten on the ground and not seeded. Feeding by tethering cattle requires the most careful attention. The land should be slightly moist but not soft enough to cause damage to root crowns by treading of animals. They should be moved forward frequently so as to clean the land and yet get plenty of food.

After the first cut there is little fear of ' blowing ' or ' hoven ' and then only at the beginning while the animals are getting used to the new food. Cases of tympanitis can generally be traced to ' senji ' (*Melilotus parviflora*) growing as a weed among the berseem. Though this *senji* is grown as a fodder crop in India it is always regarded as a harmful weed in Egypt under the name of ' handagok '. It is only suitable for hay.

Berseem makes excellent hay though there is loss on handling as it is brittle. A trial truck load of hand-baled hay was sent to Mr. Crawford, Veterinary Surgeon, Bombay. After trial in his stables he stated it was the best hay he has handled in India and was quite equal to Canadian red clover hay.

V. Future of Berseem in India.

Berseem fills a place in a country like Sind which no other crop is capable of filling. What is wanted there is a cold weather leguminous fodder crop which will grow in an alkali soil. There is ample fodder in the hot weather with *bajra*, *jowar* and natural grass, but by February and March the fodder supply invariably gets very short and cattle begin to get starved, and fall a prey in large numbers to contagious diseases. Among all the cold weather fodder crops tried against berseem at Mirpur Khas none in any way approached it. Shaftal (*Trifolium resupinatum*) was the nearest to fulfil requirements, but it was not nearly so quick a grower nor was the quality of the fodder so good. Lucerne is as good quality but when tried alongside berseem on the Landhi Government Farm was a much slower grower and a poorer yielder. It also occupies the ground in the hot weather when a valuable crop like cotton might be taken and when large quantities of fodder from *jowar*, *bajra* and maize are available. Lucerne very soon gets choked with weeds.

The present obstacles to the large development of berseem cultivation are the difficulties in getting seed and the amount of irrigation water required. The latter is considerably more than that required for wheat, the usual cold weather crop. A 200-acre seed farm has now been established in Sind fitted with a power-threshing machine and it

will be seen if the seed difficulty can be overcome. It is now in the charge of Mr. T. F. Main. Growers from other parts of India report satisfactory yields of seed and Mr. Robertson Brown at Peshawar gets good seed in addition to numerous cuts of fodder.

Berseem has also been grown in non-irrigated districts when the conditions were suitable, frequently after rice, and the results have been highly spoken of. There are many parts in India which remain to be tried.

The question of the improvement of the cattle in any district is bound up with that of fodder. So with the improvement and increase of fodder it is possible to improve cattle. Attempts to improve cattle and milk supply in the face of diminishing grazing and with the extension of crops like cotton are doomed to failure unless the fodder problem is tackled first. Berseem growing is not a speculative experiment for India, there is the existing object-lesson of one million acres annually cultivated in Egypt.

PUSA,
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Third Report on the Improvement of Indigo in Bihar

I. INTRODUCTION.

WHEN the Indigo Research Station at Sirsiah was closed on March 31st 1913, investigations on the agricultural and botanical aspects of this industry were taken in hand by the Botanical Section of the Agricultural Research Institute at Pusa. Two reports on the results obtained have been published. In these papers[1] reference was made to the importance of soil-aeration and drainage in the cultivation of indigo and also to the part played by the root-nodules in the general economy of the plant. While it is true that the views put forward have excited a great deal of interest and have been accepted by many, nevertheless it has become apparent that a few of the indigo planters in Bihar have not altogether grasped the full significance of the ideas running through these two reports. This applies in particular to the wilt of Java indigo and to its somewhat erratic occurrence in North Bihar. Our investigations clearly point to the conclusion that wilt is a starvation effect due to interference with the work of the roots and root-nodules and has arisen as a result of the continuous selection of late types in the Java mixture due to the methods in vogue in raising seed. The Pusa investigations also indicate that the natural indigo problem is largely a matter of soil-aeration and that the root-nodules play a very important part in the synthesis of *indican.*

The opportunity offered by the publication of this report has been taken to re-state, as clearly as lies in our power, the principles on which the cultivation of a leguminous plant like indigo depends and the conditions under which wilt is likely to occur. At the same time, the work in progress and in contemplation have been dealt with while in the chapter on the improvement of indigo the question of selection has been discussed in detail. It is hoped that the position of the natural indigo industry as a whole will now be clearly understood ; that the various lines of investigation will fall into their proper perspective ; that the difficulties still to be overcome will be realized and that all concerned—planters, merchants, Government and investigators—will unite their

[1] These reports were issued as Bulletins 51 & 54 of the Agricultural Research Institute, Pusa.

forces so as to place the industry on a firm and prosperous foundation. While we are convinced that this is possible, we are equally certain that no lasting good can possibly be accomplished till the working conditions of the indigo plant (the natural factory) are placed on a footing comparable with those which exist in the works in which synthetic indigo is prepared. So far, the plant has lost in the struggle with artificial indigo because one of the essential raw materials—air—needed in the natural synthesis of *indican* has been a limiting factor. The removal of this limiting factor is the first condition of progress in the resuscitation of the natural indigo industry in Bihar.

II. THE PRINCIPLES UNDERLYING THE PRODUCTION OF NATURAL INDIGO.

1. The Factors.

The species cultivated. The two species of indigo cultivated in Bihar, known as Java and Sumatrana indigo, are leguminous plants on the roots of which nodules occur. Sumatrana is a comparatively shallow-rooted annual while Java indigo is deep-rooted and behaves, in localities where the soil conditions are favourable, as a perennial. The range in time of maturity of the types constituting the Java crop is very great—some are early, others are very late and all intermediate stages occur. It is probable therefore that the root-range of Java indigo is not uniform. The early types are likely to be comparatively shallow-rooted while the late types have much deeper roots.

Soils. The soil of North Bihar in which indigo is grown belongs to the older alluvium of the Gangetic plain. Its main characteristics from the point of view of the plant are its depth, the uniformity of its fine particles, its water-holding capacity during the hot weather, the comparative nearness to the surface of the sub-soil water and the low content of oxygen in the deeper layers as shown by the analysis of well-waters. The indigo soils easily run together on the surface after rain forming a well-defined crust known to the cultivator as the *papri*. The formation of this crust is exceedingly harmful to crops, including indigo, as it interferes with the aeration of the soil.

The Bihar alluvium is not uniform. The high lying lands on which indigo is grown are generally lighter and opener in texture than the low-lying rice areas. The soil of the high lands themselves, particularly near rivers, is often made up of alternate strata, loamy and sandy in character. These facts are of importance when considering questions connected with soil-aeration and the root-development of indigo.

Climate. The climate of this region is well known. There is a well-marked cold season, in which the average rainfall is comparatively small, followed by the hot weather in March, April and May during which dry west winds are common leading to a great loss of sub-soil moisture and a corresponding amount of soil-aeration. In the monsoon phase, which lasts from June to early October, there is heavy rain (the amount and distribution of which varies greatly) sometimes accompanied by floods which kill out large areas of indigo. Wilt occurs during the monsoon, generally after the first cut is taken in June and July.

These are the main factors which must be borne in mind when considering how the cultivation of indigo can be improved. The details with regard to the ordinary cultivation of Java and Sumatrana indigo are so well known that a knowledge of these processes on the part of the reader is assumed.

2. The two nitrogen cycles in Indigo.

Indigo is grown for the sake of the *indican* in the leaves. This is a complex nitrogenous substance which yields indigo when the cut plant is steeped in water. *Indican* is manufactured by the plant from simple substances. As it contains nitrogen, the sources from which the plant obtains this element are important.

There are two nitrogen cycles in leguminous plants like indigo or, in other words, two sources from which this essential raw material can be obtained. The usual source is the atmospheric nitrogen fixed by the root-nodules. In addition, leguminous plants can use for growth, partly or entirely, the nitrates which occur in the soil. On very poor land, leguminous plants make use of the nodules only. On very rich land, they often utilize the soil nitrates exclusively. On land intermediate in fertility, both sources may be employed simultaneously.

Root-nodules. The nodules are rounded swellings on the roots of indigo which are formed soon after the seedling stage. They vary in size but are generally larger than a Sumatrana seed and can best be seen when a young indigo plant is taken up with a ball of earth and the soil carefully washed away with a watering can. Many of the nodules then remain attached to the roots as rounded, pinkish swellings. The nodules arise as a result of the invasion of the young roots (by way of the root hairs) by a certain soil organism (*B. radicicola*), the presence of which stimulates local root growth to such an extent that a swelling is formed. The invading organisms rapidly increase in numbers inside the nodule from which they derive, among other things, large quantities of carbohydrate food. This is manufactured by the leaves. The general opinion is that the organisms and the leguminous plant live together

in partnership to the advantage of both. The plant feeds the organisms while they, in return for food and lodging, assimilate nitrogen gas and build it up into complex substances which the plant can use in the formation of the proteids necessary both for ordinary growth and for the formation of flowers and seeds. The greatest development of nodules occurs just as the plant begins to flower. During this period, many of the nodules lose their substance and become little more than empty shells. It is commonly believed that the contents of the nodules are at this stage absorbed by the plant and are used up for the preparation of the large quantities of proteid required to form flowers and ripen seed. The seeds of the *Leguminosae* are always rich in proteids (4 to 9 per cent. of the dry weight is nitrogen) and indigo is no exception to the rule. In addition to water and carbohydrate food, the nodule organisms require oxygen which is also provided by the plant. This is one of the reasons why good soil-aeration is so necessary for leguminous plants like indigo. The active portions of the root, including the nodules and their organisms, breathe like animals do and so use up oxygen and produce carbon dioxide. The nodules also require free nitrogen gas and are of no use to the plant when they are immersed in water.[2] Nitrogen gas must therefore enter the nodules themselves if it is to undergo fixation. This can only happen in a well-aerated soil as the great source of nitrogen is the atmosphere.

The nitrate cycle. Nodules although common on the roots of leguminous plants are not essential for their growth. These plants are able to grow without the nodule and also to flower and form seeds. They are able to use nitrates dissolved in the soil water as their source of nitrogen. The plant can use both cycles at the same time and derive part of its nitrogen from the soil in the ordinary way and part from the nodules. Nodules are best developed in poor, open soils which are well-aerated. In well-manured soils rich in nitrates, leguminous plants tend to form few nodules and, if the soil is rich enough, none at all. It is possible therefore in the case of indigo to raise crops on very rich land which make no use of the nodule nitrogen cycle but which obtain all their nitrogen as nitrate from the soil.

These are the main facts relating to the nitrogen cycles of a leguminous plant like indigo. For the sake of clearness, the essential points are recapitulated as follows :—

(1) Leguminous plants like indigo can obtain their nitrogen in two ways—from the root-nodules or from the nitrates

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[1] Frank, *Ber. d. Bot. Ges.*, 1892, p. 271.

[2] Nobbe and Hiltner, *Versuchsstationen*, 52, 455, 1899.

in the soil. Both these methods are often employed by the plant simultaneously.

(2) The nodules make use of nitrogen in the gaseous condition and build this up into substances which the plant uses for growth and for flower and seed formation.

(3) The nodules can only do their work properly in well-aerated soils as they need both nitrogen and oxygen as gas.

(4) Nodules are only abundant when leguminous plants are grown in poor, well-aerated soil. In rich soil, such as land full of *seeth* or saltpetre, they are only sparsely developed and, if the soil is rich enough, may not be formed at all.

3. The production of colour.

The general relation between the nitrogen cycle and the production of *indican* must now be considered. In this connection, the following facts have to be taken into account :—

(1) *The contraction of the area under indigo on the Gangetic alluvium.* Formerly, there was a considerable area under indigo in Lower Bengal and the United Provinces in addition to North Bihar. With the gradual decline in the industry, the area under indigo in the tracts outside Bihar rapidly diminished and the industry only maintained itself to any extent in North Bihar chiefly on certain estates which suit the crop. The contraction of the area in North Bihar itself is significant—the cultivation has been abandoned on the heavy, badly-aerated soils of the submontane tract and on estates subject to inundation and where the soil is heavy and surface drainage is poor. On such lands, disused indigo factories are unfortunately common. Indigo in Bihar has usually survived only on well-drained, high-lying factories where the aeration of the soil is above the average.

(2) *The situation of the estates which produce the best colour.* The reputation of the various Bihar estates for colour is well known in the trade and also among the planters themselves. Other things being equal, the best marks come from high-lying, well-drained areas and the worst cakes are made from indigo growing on heavy, badly-aerated lands. There is a well marked connection between the class of soil and the reputation of the estate for colour.

(3) *Heavy dressings of seeth stimulate the indigo plant but do not increase the yield of indican.* The connection between the yield of green plant and heavy dressings of *seeth* are well known. This manure produces abundant growth but the yield of indigo given by every 100 maunds of green plant is not so high as in the case of the produce of poor land. Speaking generally, *zilla* indigo, grown on the comparatively poor lands of the *ryots*, gives a better yield of dye than *zerat* indigo from lands which are manured with *seeth*. *Seeth* is a manure rich in combined nitrogen.

(4) *The colour produced in the nodule nitrogen cycle is superior to that of plants grown in heavy rich soil bearing few nodules.* This has been observed several times at Pusa. If leaflets taken from plants with abundant nodules and also from indigo growing in heavy, rich soil with few nodules are made to deposit their indigo in the leaflets themselves, great differences are apparent. The plants in the nodule cycle yield abundant bright blue indigo, those in the nitrate nitrogen cycle yield a very dark product almost black under the microscope. The differences correspond closely with the appearance of good and inferior indigo cakes.

The above facts all fall into line on the assumption that the production of good colour depends on the activity of the nodule nitrogen cycle and takes place to the greatest extent on the high-lying lands where soil-aeration is suitable for this process. Where the nitrate cycle predominates, as on low-lying damp tracts where the soil is rich and where nodules are not formed in abundance, indigo generally yields heavy crops of leaf with a low percentage of *indican* and cakes of poor quality.

The *indican* in the plant appears to represent the difference between the total nitrogen assimilated and that used for growth and may be regarded as a reserve which can be made use of under certain conditions. Thus Rawson found in Bihar that premature flower and seed formation was associated with a distinct falling off in *indican*, a result which supports the idea that this substance can function as a reserve material. Bergtheil in the Sirsiah Report for 1908-09 (p. 16) refers to this matter in the following words :—" The *indican* content of the leaf of those indigo yielding plants which have been studied (*I. arrecta* and *Sumatrana*) is known to drop as soon as the seed sets and to decrease gradually as the seed forms, so that it seems probable that it is drawn upon to assist in the process of seed formation." In the Sirsiah Report for 1907-08

(p. 15), particular attention is drawn to the fact that "plant grown under minimum moisture conditions has invariably a high colour content." Under such circumstances, there is nothing to interfere with the aeration of the nodules and the rapid production of *indican* goes forward undisturbed. The physiology of *indican* and of the other glucosides met with in leguminous plants is still obscure and much also remains to be done in working out in detail the nitrogen assimilation in this order. However, the connection between *indican* production and the nodule cycle in the case of indigo is supported by all the facts and experience available at the moment. It also derives considerable confirmation from the conditions necessary for growth in the case of gram [1] and the geographical distribution of this crop in India.

4. The manuring of indigo.

As the production of *indican* in the plant is bound up with the efficiency of the nodule nitrogen cycle, the question arises—Can we increase *indican* production by any form of manuring ? This is one of the subjects to which great attention has already been paid in Bihar and the older reports abound in accounts of manurial experiments. The only definite fact which emerges from these trials is that nitrogenous manures like *seeth* stimulate the growth of the plant but do not increase the total amount of indigo per acre. The results obtained with the various artificial manures, on the other hand, are exceedingly contradictory and by a judicious selection of the evidence it would be possible to prove anything from the published figures dealing with these experiments. All this is at once explicable if due weight is paid to the existence of two nitrogen cycles in indigo and to the fact that unless the experimental plots are perfectly graded and surface-drained, local water-logging (by interfering with the work of the nodules) would be sure to upset any paper scheme of manurial experiments however well designed.

It is a curious circumstance that no attention has hitherto been paid to the only manures likely to be of use in indigo cultivation in Bihar namely, aerating agents like potsherds (*thikra*), brick refuse (*surkhi* and *roras*) and charcoal (*koila*). Of the previous investigators, Rawson came nearest to the discovery of the connection between soil-aeration and the production of colour. In his *Report on the cultivation and manufacture of indigo*, 2nd Edition, 1907, p. 7, in dealing with Bihar soils he states :—

"Sample No. 13 is described as an old saltpetre soil, and one would therefore expect it to contain a high percentage of nitrogen, but on the contrary it proved, on analysis, to contain a very small amount of that

[1] *Memoirs of the Dept. of Agr. in India* (*Botanical Series*), vol. VII, no. 6, 1915.

element. Indigo plant grew upon this soil exceedingly well, and the colour obtained from it was of high quality. The chief feature about the soil, as revealed by analysis, was its high percentage of available as well as *total* phosphoric acid."

The saltpetre soils are well aerated soils and generally contain *thikra* or *roras* in abundance. In such land, indigo grows remarkably well and the colour in the leaf is abundant and of good quality. It might, therefore, be found to pay to add permanent aerating agents to the land. Experiments in this direction are already in progress at Pusa and on the Dholi estate and so far the results are promising. It remains to be discovered however what is the most economic amount of these dressings to apply and also the best state of division to which these materials should first be reduced. The results already obtained on some of the Pusa plots seem to indicate that these ærating agents should be applied in comparatively small fragments. The economic aspect of such manuring can of course only be discovered on large scale plots. Two other aspects of this manuring are likely to be important. In the first place, the door will be opened to the study of intensive indigo cultivation and the production of large quantities of indigo from small areas. In the second place, aeration is likely to tend to produce indigo of uniform dyeing power and therefore to help in the standardization of the natural product.

III. INDIGO WILT.

Indigo like several other leguminous crops is apt to be affected by wilt. The deep-rooted Java species is much more liable than the shallow-rooted Sumatrana. The trouble occurs, as a rule, during the second half of the monsoon phase usually after the first cut has been taken.

The characteristics of indigo wilt. The unhealthy condition of Java indigo, locally known as wilt, is unfortunately so well understood in Bihar that only the briefest description of the affected plants is required. The trouble usually begins after the first cut and can be observed first in a few plants scattered through the field. In many cases, this unhealthy condition spreads rapidly until the whole area becomes affected. Such fields do not recover and the crop gradually dies out.

The external symptoms of wilt are quite definite—a slowing down of growth, followed by leaf-fall and a gradual change in the colour of the remaining foliage from the ordinary bright-green to a yellowish-green slaty colour. Afterwards, the plant dies off in stages, the process taking place slowly a branch at a time.

All the indications point to root trouble which further examination confirms. The main roots of the wilted plants are healthy but there

is a great lack of feeding roots and practically no nodules. The wilted plants are in reality starving in the midst of plenty on account of the fact that they can no longer assimilate atmospheric nitrogen and absorb water and other minerals from the soil. The main indigo roots, although uninjured, are unable, during the monsoon phase, to renew their root system and to form new nodules. This want of the power of repair in leguminous plants is well known and has been described previously.[1]

The occurrence of wilt. Wilt has been observed to occur on Java indigo under the following circumstances:—

(1) On the ordinary leaf crop during the monsoon. This is the indigo wilt as usually observed on indigo estates after the first cut in June or July. As a rule, it occurs during the second half of the manufacturing season. Its extent varies greatly according to the season. In some years, a few plants here and there may be wilted, in other seasons it is widespread and may cut short *mahai* altogether.

(2) On indigo sown in June at Pusa on well-drained land containing numerous potsherds. In 1912, Java indigo was sown in lines on *thikra* plots at the break of the monsoon. Practically the whole crop died of wilt by the middle of October. In one plot, a few blank spaces remained in the lines which were filled up by re-sowing in the first week of August, by which time the standing crop was badly affected by wilt. The August sown plants were not affected but grew well and gave heavy crops of well-ripened seed. Here healthy and wilted plants were growing next to next with interlocking root-systems. In no case, however, did wilt spread to the late-sown plants thereby indicating that wilt is not a disease in the ordinary sense.

(3) On old branches left at the first cut. If a branch is left at the first cut to carry on the transpiration current, it is observed that the indigo shoots much more quickly than if cut back to the ground. In some seasons, when the new growth is well-established near the ground, the old branch left begins to show signs of wilt which does not spread to the new growth. We have, in such cases, the phenomenon of a plant healthy below and diseased above.

(4) On indigo sown for seed in August and cut back in the middle of October. If young and healthy seed indigo in a vigorous condition is cut back to the ground level in

[1] Pfeffer, *Physiology*, vol. 1, 1900, p. 401.

mid-October when about a foot to eighteen inches high, most of the crop dies but some of the stumps produce a few wilted shoots. There is no question of damage by rain under such conditions and wilting here takes place on plant in perfect health. If such wilted plants are examined, it will be found that the nodules and feeding roots are dead. The main root is unable to repair itself and to form new nodules.

These are the four circumstances under which wilt has so far been observed. They must be all considered together when the question of the nature of this trouble is discussed.

The nature of wilt. A careful consideration of all the circumstances connected with the observed occurrence of wilt suggests that we are not dealing with a disease in the ordinary sense but with a starvation effect due to interference with the work of the nodules and fine roots. In the second half of the monsoon, wilt occurs because the soil has become water-logged and its porosity has been ruined to such an extent that the nodules and fine roots have been destroyed. In the case of the plot at Pusa where all the June sown plants were wilted while those sown in August were without exception healthy, the explanation is to be found in the fact that the root systems of the latter were still shallow and had not, before the end of the monsoon, reached the water-logged sub-soil in which the roots of the June plants had for some time been forced to exist. The occurrence of wilt on old branches left at the first cut is no doubt due to the fact that the branch has been starved by the new vigorous shoots on the line of communications which have absorbed most of the materials coming from the roots. In such a case it would be possible for wilt to occur on one part of the plant without the destruction of the nodules. The wilt which occurs on healthy August sown plants cut back in mid-October probably arises from the direct starvation of the nodules. At this stage, little or no reserves have been laid down in the main root and in the base of the stem. At the same time, the removal of the stem and leaves cuts short the food supply of the nodule and starvation results. In most cases, the nodules and fine roots die in a few days and no new shoots are formed. In some instances, the stumps are able to produce a few weak wilted shoots and the plant may linger on during the cold weather. In all such plants examined, nearly all the nodules were dead and the remainder were discoloured.

A consideration of these facts leaves little doubt that wilt is a starvation effect. If it were a disease, the organism connected with it would have to be isolated and the disease reproduced in inoculation

experiments. So far this has not been accomplished. If wilt is a disease, an explanation will have to be found of the occurrence of the wilted June sown plants and healthy August sown plants growing side by side at Pusa in 1912.

The distribution of wilt is sometimes exceedingly erratic. On this account, some planters have experienced difficulty in understanding that it is a starvation effect. Indigo on light, high-lying lands may suffer severely from wilt while the crop growing on heavy, badly-drained, water-logged land near may either escape altogether or may be affected only to a slight extent. At first these facts appear to contradict the view that wilt is a starvation effect often caused by water-logging. If this is so, it is argued that there should be less wilt on the high lands and more on the badly-drained, low-lying, water-logged fields.

Such cases are easily explained if all the facts of the case are taken into consideration. The chief fact to remember is that indigo can do without the nodule cycle and can make use of nitrate nitrogen. This is most likely to happen on low-lying, rich, moist soil somewhat close in texture such as that which is often cultivated during the hot weather by the people for their food crops. In such situations, few nodules are formed and indigo will live with its roots immersed in water provided the supply of oxygenated water, nitrates and other dissolved salts is adequate. To all intents and purposes the indigo would be growing as in water culture and no damage would result from long immersion. Indigo using the nitrate cycle on heavy land can therefore often live for a time when the land is under water. The case of indigo using the nodule cycle on high-lying, light land is quite different. The nodules die comparatively quickly when the air-supply to the roots is cut off by long-continued rain. The nitrate cycle cannot be used as the light soils are often poor in this substance during the rains. Further, the indigo plant under such circumstances has lost the power of repair and cannot form new nodules. The result is wilt. The presence of a few wilted plants in a field which is not followed by the spread of the trouble is explained by the fact that some types of Java plant are much deeper-rooted than others. The incidence of wilt will naturally depend on the distribution of the root-system.

The extent of wilt in any one year or on any particular estate depends on a variety of circumstances and it is not always possible to correlate the amount of the damage done with the rainfall. Wilt will only become important when the aeration of the soil is completely destroyed for some time. This naturally depends on other things besides the total rainfall. The amount of air in the soil at the beginning of the monsoon will vary with the previous monsoon, the winter rainfall, the occurrence

of west winds and the amount of the hot weather rainfall. Generally speaking, a dry hot weather and long-continued, west winds will be factors tending to lessen wilt. A damp hot weather with east winds will have the reverse effect. During the monsoon, the distribution as well as the amount of rainfall is important. Heavy falls with long breaks often destroy the soil-aeration less than a constant succession of showers all of which are absorbed. The rise of the sub-soil water level is another factor. The nearer this gets to the surface the less the air in the soil and the quicker does complete water-logging occur.

The spread of wilt in Bihar. When Java indigo was first introduced into Bihar, it did exceedingly well and was noted for its rapid growth and general robustness. After a few years it seemed to slow down in growth and wilt began to appear. The crops kept for seed yielded less and less and soon the seed-problem became acute. Between 1910 and 1914, the area under Java indigo in Bihar decreased from 70,000 to about 15,000 bighas largely on account of wilt and the difficulty of obtaining seed.

The explanation of these facts is a matter of considerable interest both from the practical and scientific standpoints. The principal cause of the degeneration of the plant is undoubtedly to be found in the methods in vogue in Bihar in growing seed. It used to be the custom to keep the old leaf crops for seed. For a time, good crops of seed were obtained and it was not till some years had elapsed that the Java crop began to show signs of want of vigour and finally began to die of wilt. The degeneration was progressive.

The explanation of the falling off of vigour is a simple one if two facts are borne in mind. Firstly, Java indigo is exceedingly mixed and contains early, intermediate and late types. The early types are comparatively shallow-rooted while the late forms have deep roots. Between these extremes all gradations occur. Secondly, indigo does not set seed in Bihar till after the middle of October and the flowers which open before this period only give rise to empty pods. This is due either to the dampness of the air affecting the pollen, to the absence of bees or to both these causes. Every planter must have noticed that when a Java leaf crop was kept on for seed that many pods were formed in September and early October which contained no seed. The early plants gave little or no seed and the main seed crop was obtained from the late-flowering types. It requires little imagination to understand the cumulative effect of this unconscious selection. The early, shallow-rooting, quick-growing types would slowly become eliminated and the late deep-rooting, slow-growing types flowering after mid-October would tend to predominate. In the course of a few years, the botanical

constitution of the crop would change. The Java crop would become more and more made up of slower-growing, deep-rooted types. It is just these deep-rooted forms which in an alluvial soil like that of Bihar would, during the monsoon phase, be apt to be attacked by wilt. Shallow-rooting, quick-growing kinds would be much less liable. The main cause of wilt is undoubtedly the unconscious selection exercised by the old method of growing seed. There are also two contributing causes to be mentioned—the gradual rise in the high flood level and wet seasons. These, however, are of minor importance compared with the alteration in the botanical constitution of the crop.

Remedies. It will be seen from the foregoing that no remedy can possibly be devised to cure an indigo plant affected by wilt. While cure is out of the question, prevention is not a difficult matter. Two things are necessary to achieve this object which will not only reduce wilt to insignificance but also increase the yield of indigo per acre.

(1) The Java crop must be brought back to its original condition. Instead of making the crop later and increasing the depth of its root-system by eliminating all the early plants, we must work in the opposite direction and select for earliness, rapid growth and shallow roots. The old method of growing seed must be given up and a special August sown crop grown instead. All weak, late-flowering plants in this seed crop must be cut out and destroyed and only the early-flowering kinds must be left. The seed crop must be rogued twice every year—once before flowering begins and again when it is well in progress. Every weak-looking, late-flowering plant must be ruthlessly destroyed and regarded as a wilt producer. This procedure must be continuously applied to the present crop in Bihar and also to the seed obtained from Java. In a short time, the crop will be brought back to its old vigour and wilt in Bihar will become of small importance.

(2) Every possible means must be taken to improve the aeration of the soil. The protection of the aeration of the soil of the higher indigo areas is a matter of surface drainage. If we divide up the area by trenches as has been done at Dholi and get rid of the run-off at once, each field will have to deal with its own rain only and will not be subjected to surface drainage water. Such a system is bound to protect the plant and to assist it in resisting wilt. The improvement of the general drainage of Bihar as a whole

and the prevention of floods will act in the same direction.

The mere introduction of new seed from Java is of no value as a remedy for wilt. The crop raised from this seed is affected in a similar manner to that produced from local Bihar seed. The cultivation of indigo in Java has fallen considerably in recent years. According to the account of this crop given in van Gorkom's *Oost-Indische Cultures* (vol. 3, p. 18, 1913) the production of indigo fell from 14,677 maunds in 1903 to 1,613 maunds in 1910. This is confirmed by the experience of the Hon'ble Mr. Keatinge, C.I.E., Director of Agriculture of Bombay who visited Java in 1913 and who has kindly sent us the following information (Letter, dated Poona, August 28th, 1916) :—

"When I was in Java I was on the lookout for indigo seed for you, but was told everywhere that there was very little grown now in Java and none at all on an organized scale. I could not find that any of the Companies grew it, and the only place where I saw it grown was at Djokjakarta where a good deal is grown in small plots by natives for their own use. When I was there in December the crop was still young. From what I saw I feel fairly sure that it is no longer grown on a commercial scale or under skilled supervision in Java."

Importers of Java seed often comment on the difference in quality and germination power between that now obtained and the supplies of ten years ago. The seed now imported is raised by the natives who according to van Gorkom (p. 32) take no care in selecting their seed. When grown by the Dutch planters, the production of seed was a matter to which great attention was paid. It appears therefore that both in Java itself and also in Bihar the botanical constitution of the main crop has altered in a similar manner and is now largely composed of deep-rooting, late types. These late types, however, do not breed true, but give rise to a certain number of early quick-growing forms. By a careful continuous selection of these early types it is practically certain that the old Java indigo, which did so well in Bihar, can be recovered.

Of late years wilt has sometimes made its appearance in fields of Sumatrana indigo. The explanation of this occurrence is doubtless due to a change in the type of plant cultivated. It is well known that in recent years a good deal of seed has been brought from the Punjab and mixed with the Cawnpore type before sale to the planters. These North-West types are deeper rooted than the Cawnpore plant and are therefore more liable to wilt in Bihar. The remedy in this case is to preserve the old Cawnpore plant and to supervise the production and sale of the seed.

IV. THE CULTIVATION OF INDIGO.

The cultivation of indigo is largely a matter of soil-aeration. The aim before the planter is a simple one namely, the production of the maximum amount of indigo per acre in the shortest possible time. After the end of July, the crop is always liable to damage by wilt and floods so that it is a great advantage to force on the growth and secure the second cut during the latter part of this month. The directions in which the plant can be assisted in its work fall naturally under two heads—cultivation and drainage. These two matters will be considered separately.

Cultivation. It is in the cultivation of Java indigo that improved methods are particularly necessary. The preparations for sowing Sumatrana at the beginning of the hot weather have reached a high level with the means available and no very great room for improvement appears to exist as far as this species is concerned. In the preparation of the land for the Java crop however, insufficient attention is often paid to the aeration of the soil. As is well known, the Bihar alluvium becomes densely packed by the monsoon rains and is often on the moist side when the sowing time for this crop comes round in October. A thorough cultivation of the soil before sowing and the formation of a good aerated tilth have a wonderful effect on the young seedlings. Their root development is stronger, abundant nodules are formed and the plants come away well in late October and early November. Want of cultivation on the other hand, particularly when the soil is on the wet side, leads to a stunted crop very liable to attacks of *Psylla.* Planters will find it to their advantage to bestow more care on their preparations for sowing Java indigo for leaf and to bear in mind they are dealing with a leguminous plant whose future, as an indigo producer, depends on a copious development of roots and root-nodules.

The cultivation of both Java and Sumatrana indigo during the hot season is a matter to which adequate attention is only now being paid. During this period, two things are necessary—the removal of weeds (which rob the soil of moisture and minerals and check the branching of indigo) and the formation of a surface mulch of several inches of loose, dry soil to conserve the moisture and check burning. Even on the best managed estates it is doubtful whether the indigo is cultivated enough during the hot weather. It is still possible to see stretches of plant competing with weeds in land the surface of which is much too hard and firm to the tread. Formerly, indigo fields were hand-weeded but the results were not satisfactory and the expense was considerable. The crop can be weeded and the mulch of dry soil produced by means of the Canadian lever-harrow, the tines of which can be adjusted to suit

the stage of development of the growing indigo. Immediately the cover crop is removed in March, the young indigo should be cultivated with these harrows and, as the plants develop, a deeper and deeper mulch of dry soil should be produced. Weeds are at the same time pulled out and the *papri* is broken. About the beginning of May, the crop should be sufficiently advanced to stand cultivation with the spring-tine cultivator [1] by which a mulch of dry soil about three inches in depth can be produced. The effect of this cultivation is to stimulate growth, to remove weeds and to leave a thick mulch of dry soil. This soil mulch preserves moisture and checks burning and also serves to absorb all the early monsoon rainfall. The result is extremely rapid growth and the hastening of the time of the first cut.

After the first crop is taken, the indigo roots produce shoots for the second cut much more quickly if a branch is left to maintain the transpiration current. This is a great advantage as the sooner the second cut is taken the better. It often happens that wilt appears on the old branch as soon as the new basal shoots are well established. This has been referred to above and is merely a starvation effect and does not involve the wilting of the new growth.

After the second cut has been removed, the crop should be dug out and the land got ready for *rabi* crops. It does not pay to keep the old stumps for a seed crop as by this means the land becomes exceedingly foul with weeds and the quality of the seed so obtained is generally poor and often small in amount.

Drainage. As the well-being of the indigo crop, other things being equal, depends on the aeration of the soil, it follows that any means of protecting the porosity of the land from damage by rain and flood-water must prolong the life of the plant and increase the yield of indigo. One of the factors which destroys the tilth and cuts off the air supply to the roots is the rainfall. This we cannot control and it may sometimes happen that this factor alone will be sufficient to destroy the aeration of the soil and bring on wilt.

There are, however, two factors besides the direct rainfall which affect soil-aeration. These are the run-off (the portion of the rainfall not absorbed by the soil) and floods. The run-off (often referred to as surface drainage) is perhaps more detrimental to indigo than floods as the former damages the crop every year whereas floods occur only about once in four years. The run-off acts as extra rainfall and land subject thereto loses its porosity and therefore its power of maintaining its air

[1] The Canadian lever-harrows referred to can now be obtained from Messrs. Octavius Steel & Co., Calcutta, who are the Indian Agents for these implements. The five tine, spring-tooth cultivator is sold by Messrs. A. Butler & Co., Mozaffarpore, and by Messrs. Volkart Brothers, Lyallpur, Punjab.

supply much more rapidly than fields which have to deal with their own rainfall only. The control of the run-off is a simple matter and can be achieved by the Pusa method of surface drainage now to be seen in operation on the Dholi estate.[1] This system consists in dividing the *zerats* into suitable blocks, each about five bighas in extent separated from one another by trenches provided with grass borders. The run-off of each field passes over the grass borders into the trenches and is led to the drainage lines. Fields at a lower level are thus protected and have to deal with their own rainfall only. Incidentally, the fine soil is retained on the land and such fields level themselves and rapidly increase in fertility.

Floods affect the well-being of the indigo crop in several ways. Complete submergence of the plant for any length of time naturally destroys it. On light poor lands, where the nodule cycle is important, the flooding of the land either kills off the indigo at once or leads to wilt. Submergence of the land in which the indigo depends on the nitrate nitrogen cycle may not in all cases, as explained above, destroy the crop. Even where the high lands are not flooded, any great rise in the water level at once affects the sub-soil and renders it much moister than before. The affected indigo may not actually wilt but it often begins to change in colour and to drop its leaves. An interesting case occurred at Pusa in October 1915 when the late flood markedly affected the amount of moisture in the sub-soil and led to the production of much yellow leaf followed by leaf-fall. Floods are also detrimental in interfering with the efficiency of a surface drainage system by blocking the outfalls and so preventing the draining away of the run-off.

The prevention of floods is naturally a more difficult matter than the control of the run-off. It is, however, of great importance to the future of the indigo industry and to the agricultural development of North Bihar. This tract of country consists, as is well known, of a series of alternate ridges and low-lying areas which run roughly parallel to the rivers. A section at right angles to one of the rivers would pass through a series of these raised folds and low-lying depressions. The indigo factories occur on the ridges and rice is cultivated in the depressions. During the monsoon, the sub-soil water level rapidly rises and the rice areas fill up with storm water. The monsoon water-level is now often so high that only the ridges remain above water. When a flood comes down from the hills under these conditions, the water-level rises still more and some of the ridges with their indigo fields go under water and are destroyed. No local system of surface drainage, however perfect,

[1] For a fuller account of this system of surface drainage and of its advantages the reader is referred to Pusa Bulletin 53.

is of any avail against such floods. There is total submergence for some days till the overworked drainage lines can again lower the water-level. Serious as is the occurrence of these floods, a still more ominous circumstance is the fact that the high-flood level is slowly rising at the rate of about three inches a year. The result is that the air-spaces in the soil become more and more replaced by water and the area of indigo killed out increases. Experienced planters say that this continuous rise in the flood-level is caused by embankments (canal, rail and road) which interfere with the natural drainage of the country and indirectly silt up the water-ways. There can be no doubt that they are correct and that in the development of North Bihar far too much attention in the past has been devoted to communications and that little or nothing has been done to maintain and improve the water-ways. The rivers and drainage lines in an agricultural country are far more important than roads, railways or canals. The rivers and their tributaries are the natural drains of the country which carry off the surplus water and prevent the land becoming a swamp. Anything which interferes with this river action in the monsoon helps towards swamp conditions in two ways—by holding up water and by causing silt deposition in the channels. When the flow of a river is checked, silt begins to deposit and the bed is raised. The river thus becomes less efficient and as this proceeds it overflows its banks more frequently. In the construction of practically every bridge over the small rivers and drainage lines in North Bihar, too much attention has been paid to economy. In erecting these bridges, an earthen embankment is generally thrown across from each bank of the drainage line and a little bridge is put in in the middle to save iron-work. The result is that the high-flood water-way is partly obstructed ; water is held up longer than is necessary while the deposition of silt slowly blocks up the channel. Besides such embankments, the Tribeni canal, which crosses the drainage lines near the Nepal frontier and sometimes converts the country to the north into a huge reservoir, is said to be a potent source of mischief. The bursting of this mighty artificial lake is often too much for the overworked rivers and, in 1915, great damage was done.

The remedy for this state of things is the immediate construction of a drainage map for the whole of North Bihar on which the various drainage lines and the impediments to the free flow of water are accurately recorded. With this map as a basis, obstructions to the natural flow of water can be removed and the Executive will possess a powerful means of control in the future. No new machinery is immediately necessary for dealing with this matter. The District Boards possess the funds and Embankment Committees exist for dealing with such subjects

On both of these bodies the indigo planters are strongly represented. The improvement of the general drainage of North Bihar is the foundation stone on which the fabric of a rejuvenated natural indigo industry can be reared.

V. SEED SUPPLY.

Java indigo. The importance of a reliable source of seed of Java indigo needs no explanation. If the supply can be produced locally, a large amount of money will be saved and a great source of anxiety to the planters will have been removed. Now that the improvement of the Java crop by selection is in progress, it is more than ever desirable to discover methods of seed growing which are quite independent of the season and which can be taken up on the estates themselves.

Considerable attention has been paid to this matter at Pusa. The first point that has been proved is that seed growing must be regarded as quite separate from ordinary indigo cultivation and that the former practice of keeping on old indigo for seed must be given up. A special seed crop should be sown in early August which afterwards can be kept for leaf. In ordinary years, as has been demonstrated at Pusa and at Dholi, this operation presents no difficulties and exceedingly fine crops of well-filled seed can in this way be obtained. As no setting takes place unless the flowers are visited by bees, the seed crop must be well-spaced and the plants allowed to branch. If grown in the ordinary way, the plants are much too close together and only a little seed is formed on the tips of the branches.

In a year of heavy July and August rainfall combined with floods. the matter is, however, not so simple. Such a season occurred in 1915 when, on many estates, the August sown seed crop was more or less a failure. As the experience obtained in that season furnishes valuable confirmation of our views on the importance of soil-aeration in indigo growing, the facts of the case must be stated in some detail.

The monsoon of 1915 in North Bihar was heavy and well-distributed and, in addition to the rainfall, there occurred a series of floods which, on most estates, cut short indigo manufacture and killed out large areas of the crop. The weather during the first half of August—the period when Java indigo has to be sown for seed—was very wet and few breaks occurred. The almost continuous rainfall after the seed crop was sown, coming as a reinforcement to the heavy falls in July and to the floods, so consolidated the soil and interfered with its aeration that on a comparatively few estates only did the seed crop do well. It was only in cases where the surface drainage was good and the natural aeration of the soil was above the average that Java indigo sown for seed was able

to grow normally and produce an average outturn. On the heavier soils in the sub-montane tract and on th e lighter lands which had been flooded previous to sowing, the soil-aeration was so interfered with that the seed crop was attacked by *Psylla* and wilt and proved a complete failure.

At Pusa, a normal yield of seed was only obtained on two of the highest plots in the Botanical Area. The indigo on these areas, which were perfectly drained, behaved as in a normal season. Three plots at a lower elevation did not do nearly so well. After the last flood in October, the soil and sub-soil became much wetter (due to lateral percolation from the Gandak), the leaves began to turn yellow and leaf-fall commenced. The crop was saved from destruction by a deep cultivation with the *kodar* which gave the roots the necessary air. The late flood kept the sub-soil water high and so prevented the soil-aeration which follows the usual fall of the ground water in September. The three plots in question gave a moderate yield of good seed but it was not till the hot weather began in February that the foliage really became normal. This experience as well as that on many estates shows how much the prospects of the seed crop depend on the rainfall and on the fall of the ground-water towards the end of the monsoon.

In the case of Java indigo sown for leaf in early October on the higher lands, quite different results were obtained. After sowing time, little or no rain fell till March and so there was nothing to interfere with the natural aeration of the soil. In many cases, this leaf crop gave small quantities of excellent seed in February, a phenomenon which does not often occur in years when the normal amount of cold weather rainfall is received.

This experience agrees, in all respects, with the results of the various experiments in growing Java indigo for seed at Pusa. Seed formation, other things being equal, is a matter of soil-aeration. If ample air for the roots is provided a full crop of seed is obtained. If heavy and long-continued rain after sowing interferes with growth, the crop is bound to be below the average.

It has been shown that in ordinary seasons August sowings on high, drained land are all that is necessary to secure the seed crop. Some means, however, must be discovered of obtaining seed in wet years like 1915. Several methods of accomplishing this result are being tried. If theseed crop is sown fairly thickly, it might easily be possible by means of the lever-harrow on the young indigo to increase the aeration very considerably during the breaks in the rains. As soon as the crop is strong enough towards the end of September, the spring-tine cultivator could be used to increase still more the depth of the aerated soil and in doing

so half of the remaining crop could be removed. After the *hathia*, the land could be tumnied with the *kodar* (mattock) after which air would find its way to the deeper layers of the soil. In ordinary years, such a treatment does the seed crop a great deal of good. In a year like 1915, it made all the difference between success and failure and the expense was well repaid.

Besides cultivation during the early stages of the seed crop, the possibility of improving the aeration of the soil by means of *thikra* remains to be considered. At Dholi, it was noticed in 1915 how much faster the October sown indigo developed in a field in which *thikra* occurred. The growth was twice that on the land which contained no potsherds. At Pusa very good results have been obtained on such land and it might easily pay to make special *thikra* fields for seed indigo. Experiments on this point are in progress both at Pusa and Dholi and it is expected that the first set of results will be obtained next cold weather.

In addition to adding *thikra* to the land, the provision of sub-soil drainage may prove to be necessary in very wet seasons. Preliminary results obtained at Pusa indicate that this method is likely to be successful. The method is being investigated and as soon as possible will be tried on an estate scale.

A further point connected with seed growing is under investigation. It has been observed in the past that indigo forms the best seed on rather poor land and that rich soil is a disadvantage. Similar observations have been made on gram and other leguminous crops. Soil-aeration for these crops is of the greatest value in seed formation but rich soil, even when combined with improved aeration, leads to rank growth and a poor yield of seed. If, as we suspect, indigo behaves in the same way the point will be important as many of the indigo *zerats* are on the rich side due to extensive dressings of *seeth*. The experiments on this point at Pusa ought to yield definite results this year.

The storage of Java seed offers an obvious solution for tiding over an unfavourable year like 1915. In ordinary years when crops of at least twelve maunds to the acre can be grown, it would be easy to dry the seed and seal it up in sheet iron bins of the Pusa pattern.[1] Such seed would keep for several years and thus estates would be independent of the season.

Sumatrana indigo. Some attention has also been paid at Pusa to growing Sumatrana indigo for seed. Two varieties were tried—Madras and Cawnpore—and both were sown in August. In each case good

[1] For a description of these bins see *Agricultural Journal of India*, vol. X, p. 299, 1915. They are now manufactured by Messrs. Burn & Co., Calcutta.

seed was produced but the yield was small. The prospect of growing the seed of this species at a profit in Bihar does not appear very promising. The seed supply will become important however if any considerable improvement in this species is obtained by selection.

The regulation of the present seed supply of Sumatrana indigo from the Cawnpore region is a matter of importance. Some system of inspection of the fields and the purchase of the whole crop by the Bihar Planters' Association would prevent adulteration with poor quality seed from the North-West and would also help to regulate the price. This is primarily a matter for the planters themselves. It concerns the investigator, however, as well for until the seed supply of Sumatrana is properly controlled, there is not much point in attempting to improve this crop by selection.

VI. THE IMPROVEMENT OF INDIGO.

1. Java indigo.

The introduction of Java indigo. The introduction of the Java plant into Bihar agriculture in 1898 by Mr. H. A. Baily was an important event in the history of the natural indigo industry. This species is much richer in indigo than Sumatrana and also gives a higher weight of leaf to the acre. Until it became affected by wilt in recent years, great hopes were entertained that by its means the decay in the Bihar indigo industry could be arrested and the competition of the synthetic product successfully withstood.

Natal indigo. Java indigo is said to have been introduced into Java from Natal where it was found growing in the wild state. Java indigo, as grown by the Dutch planters, is however quite a different plant from the wild indigo of Natal. In 1913, through the good offices of Mr. F. B. Smith, Secretary of Agriculture to the Government of the Transvaal, the seeds of single plants of the wild indigo of Natal were separately collected in that country for growth at Pusa. In this way, a strict comparison was possible between the real Natal indigo and the Java plant. The seeds of the various Natal plants were sown separately in rows next to next so as to determine to what extent the progeny of a single parent showed any marked variation. The rows were remarkably uniform in themselves and there were no great differences to be observed between the various lines. Natal indigo proved to be erect in habit with little-branched, green stems and the foliage was somewhat sparse. The reddish stems and leaves and the much-branched habit of many of the types found in Java indigo were entirely absent. As regards susceptibility to *Psylla* and

wilt, the Natal plant showed far less resistance than the Java cultures growing side by side. This fact, combined with its erect habit and poor branching left no doubt that, from the agricultural point of view, Natal indigo is usuitable for cultivation in Bihar. This agrees with the experience of several of the Bihar indigo planters themselves.

Constitution of the Java crop. Java indigo is by no means so uniform as the Natal plant. It consists of a mass of forms differing in habit (from erect to much branched types) ; in colour of the stems and foliage(greenish, intermediate and reddish) ; in size and shape of leaflets, in time of flowering and also in root-development. The range is extraordinary and the occurrence in the mixture of forms resembling Natal indigo lends colour to the idea that Java indigo arose from a cross between the Natal plant and the species formerly cultivated in Java. At first sight, Java indigo appears to afford an ideal selection ground for the plant-breeder. Before, however, the question of improvement by selection can be considered, the methods of pollination and of fertilization in this species must be studied in detail. It is only on such evidence that correct methods of improvement can be founded.

Pollination. The method of pollination of Java indigo was studied by Parnell at Sirsiah and in the last report of that station he described the results of this investigation as follows :—

" Examination of the flower of *I. arrecta* reveals a mechanism designed to ensure extensive cross-fertilization. The style projects through the ring of anthers and carries the stigma into the closed apex of the keel where it is protected from contact with the pollen liberated lower down in the keel by the bursting of the anthers shortly before the flower opens. By carefully exposing the stigma of an unsprung flower one can see that it remains free from its own pollen in almost every instance. If the spring mechanism is not released the flower remains in this condition for several days when it begins to fade and the pollen may gain access to the stigma and produce self-fertilization. This latter event however occurs rarely ; this may be due partly to the fact that the pollen does not always reach the stigma and partly to the fact that the pollen of an old flower possesses considerably less germination power than when it is fresh, a fact readily demonstrated by germination tests done in an agar solution containing 15 per cent. cane sugar.

Normal fertilization appears to be brought about through the agency of insect visitors. In the young open flower, a state of tension exists between the ovary and the keel. The latter exerts a strong downward pressure on the ovary and is kept in position by means of a fold of its free edge on each side, the two folds coming together for a short space

over the ovary about the middle of its length. Two projecting spurs of the keel, one on each side level with the folds, support the wings as a level platform over the keel. When an insect alights on this platform the spurs are depressed, thereby separating the folds and releasing the ovary. The wings and keel spring down, owing to a sudden bending at their base, till they are about at right angles to the ovary which has jerked suddenly upwards. The stigma comes into immediate contact with the under side of the insect which is also covered with a cloud of pollen ; in this way the stigma receives a mixture of pollen from the flowers already visited by the insect. This operation may be observed very readily in the field, being effected most commonly by *Apis florea* and *Halictus gutturosus*, two common Indian bees, both of which visit flowering indigo plants in large numbers."

During the past three years we have examined the flowers of Java indigo in detail and our observations confirm and extend those of Parnell. The details relating to the flowers and the method of pollination can be seen in the Plate. There is no doubt that pollination by means of bees is the rule in this crop and that in the absence of these insects little or no setting takes place. To prove this, a number of large healthy indigo plants, which had been grown from seed sown at the end of August, were covered with frames over which mosquito netting had been stretched. The plants were put under the frames before any flowers had opened and the bases of the frames were sunk a few inches in the earth to ensure the complete exclusion of insect visitors. In all cases practically no pods formed, the flowers remaining open for a few days and then drying up. The covered plants grew, if anything, better than those outside. The ordinary uncovered plant set seed in abundance and the contrast in this respect between the covered and uncovered plants was most striking. In each of the covered plants one branch was allowed to grow outside the net, an arrangement having been made for this purpose which excluded insects. The branch growing out into the free air in all cases set seed, thereby proving that the failure to set seed on the part of the covered plants was not due to any weakness of the plant itself but solely to the exclusion of insects.

The absence of more than very occasional setting under nets although the stigma is often in contact with its own pollen, is not

Description of Plate.—1, a flowering branch of Java indigo. 2, a complete inflorescence. 3, a ripe pod. 4, a flower bud showing the relative position of the anthers and stigma just as the pollen is liberated. 5, a fully opened flower. 6, a sprung flower. 7, the keel seen from above showing the projecting spurs and folds. 8, half the keel seen sideways showing the fold which keeps the young pod in place. 9, the position of the leaflets at midday. 10, a leaf in early morning. 11, the position of the leaflets at dusk


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confined to Java indigo. It is a common occurrence in that group of the *Leguminosae* in which fertilization is largely dependent on insect visitations. Sumatrana indigo behaves in exactly the same manner. Another interesting local example is *sanai* (*Crotalaria juncea*). In such cases for fertilization to take place, it is not only necessary for pollen to come in contact with the stigma but the stigma must itself be stimulated by rubbing such as occurs when the indigo flower explodes and the stigmatic surface strikes somewhat violently the underside of the body of the bee.

Natural cross-fertilization. The fact that practically no setting takes place under nets and that for seed formation to occur the visits of bees are necessary, points to the existence of extensive natural crossing. We should expect to find that the crop is a mass of complex hybrids which do not breed true from seed. In order to verify this point and also to compare the progeny of single plants, the seed of a large number of individuals of the 1913 crop was collected separately and sown singly in lines, next to next, the following August. None of the plants bred true but gave rise to mixed cultures, thereby confirming the occurrence of extensive natural crossing in this crop. Variation due to crossing took place in many obvious characters such as the colour of the stem (greens, intermediates and reds), time of flowering, habit of growth, size of leaves, amount of total leaf surface and rapidity of growth.

Vigour of plants from self-fertilized seed. In all crops where cross-fertilization is the rule and little or no setting takes place in protected flowers, it is particularly necessary to determine whether or not there is any lack of vigour in the plants raised from self-fertilized seed. So far as the evidence obtained at Pusa goes, the indications are most definite that Java plants raised from self-fertilized seed, even in a single generation show a marked falling off in size and general vigour. If an attempt were made to purify the Java hybrids and to obtain a plant breeding true with high indican content, the experiment would, in all probability, fail in a few years on account of self-sterility. Equally weak plants are generally obtained if a similar attempt is made in crops like maize. Experience teaches that in such cases there is no advantage to be obtained in trying to avoid crossing and to secure plants breeding true to type by continued self-fertilization. Such attempts at in-and-in breeding fail through loss of vegetative vigour. It is better to control crossing in such cases as Java indigo than to attempt to prevent it.

Indican content. One of the factors that must be considered in the improvement of Java indigo by selection is *indican* content. That the various individuals constituting the mixture known as Java indigo

differ considerably in *indican* content seems exceedingly probable on general principles and is confirmed by Parnell's statement that these differences actually do occur in the field. The profitable utilization of such differences however is quite another matter. What is the meaning of *indican* content? Considered physiologically, the *indican* in the plant represents roughly the difference between the total nitrogen assimilated and that used up for growth. *Indican* content, as we know, varies greatly with the environment and is usually highest in slow growing plants. Other things being equal, we should expect a higher *indican* content in slow growing, late types than in rapidly developing early sorts. This is supported by the trial of a rapidly growing type of Java at Dholi this year which gave somewhat less indigo per 100 maunds than the general crop but made up for this by an increased yield of plant per acre. Conversely, the late Madras type gave more *indican* per 100 maunds than the early Cawnpore Sumatrana. Bergtheil (Sirsiah Report for 1906-07, p. 19) found that the *indican* content in the slow-growing Multan type of Sumatrana was higher than in the rapidly-growing Delhi-Cawnpore variety.

In selecting on the basis of high *indican* content for Bihar conditions we are likely to encounter a serious difficulty. The plants richest in *indican* will probably be slow-growing, late kinds which will not fill the planters' carts and which may be caught by wilt and floods in the second half of the season. What the planter wants is a rapidly-growing Java plant which is a cart-filler and which can make the most of the early safe monsoon period. The investigator, in following the line of high *indican* content, is more than likely to fail. He may succeed in getting a type high in *indican* but it may be of no practical advantage to the planter. In a country like India where the season is everything, experience teaches us that it is best to play for safety and not to take risks. It is always advantageous to cultivate types which will ripen wel within the season and to avoid late kinds which only succeed now and then. Every planter will agree that the period June and July is far more important in indigo manufacture than August and September and that the sooner the first two cuts are carted the better. The planter's object in growing indigo must at this juncture be clearly kept in mind. It is to secure the maximum amount of indigo per acre, *not to grow the type which gives the highest yield per 100 maunds of green plant.* The highest yield per acre under Bihar conditions may easily be obtained by types which are by no means the highest in *indican* content.

Methods of selection. In the improvement of plants everything depends on the adoption of the right method. The method or methods in any particular case depend on an accurate understanding of the facts

dealing with pollination and fertilization and a correct appreciation of all the working conditions, botanical as well as agricultural.

In the present case it will be an advantage, before dealing with the actual methods which can be adopted, shortly to recapitulate the working conditions. These are :—

(1) Cross-pollination by bees is the rule and little or no setting takes place in the case of protected flowers. Artificial self-pollination is difficult and does not yield much seed.

(2) The crop, as ordinarily grown, consists of a mass of complex heterozygotes, that is, of plants which do not breed true.

(3) The seed of self-pollinated flowers gives rise to offspring lacking in vigour compared with the plants raised from ordinary seed. The occurrence of self-sterility is practically certain in Java indigo.

(4) The types composing the crop vary greatly in rapidity of growth and time of flowering. Some develop quickly and flower early, others grow much more slowly at first and only begin to flower towards the end of the season. This range in time of flowering is correlated with the development of the root-system—the early sorts are shallow-rooted while the late kinds are deep-rooted.

(5) The types vary in *indican* content and there is evidence for believing that the early kinds contain less *indican* per 100 maunds than the late slow-growing kinds.

(6) The best method of obtaining seed of Java indigo is by August sowings and not by keeping on the October sown leaf crop for seed.

(7) The time during which the work dealing with chemical selection has to be carried at is very limited. This must be done during early October before flowering begins and the plants tested must be in a similar stage of development.

A study of the working conditions discloses the fact that the improvement of the Java crop by selection will not be easy. Methods of selection such as can be applied to crops like wheat in which self-pollination is the rule and in which cross-pollination is rare are out of the question. Methods which can be adopted in crops like tobacco which set seed freely under nets are equally eliminated. Selection which depends on artificially selfing protected plants is put out of court by the occurrence of self-sterility. One set of methods only remains—those which depend on the control of natural crossing. In many respects,

these are the least satisfactory of all the methods of selection as the process to be effective must be continuous.

Three methods of selection are possible in Java indigo, in two of which considerable progress has already been made at Pusa.

(1) Selection of mixed early types. As has already been indicated in this report, the advantages of rapid maturity are likely to outweigh all other considerations. If, therefore, the seed of a large number of promising early individuals is collected separately and sown in lines, a comparison can be made among the offspring as regards earliness, vigour and rapidity of growth, branching power and general agricultural fitness. The best cart-fillers can thus be picked out and the weak lines eliminated. The lines which remain can then be gone over and all the weak and late-flowering plants removed. The seed of the remaining plants is now mixed and sown on the large scale. Careful elimination of unsuitable plants is carried out before flowering begins and a second elimination a few weeks afterwards will serve to remove all late flowering individuals. When sufficient seed has been obtained, the early mixture can be given out to estates. The seed crop should be subjected to similar careful selection every year. This can easily be done on the estates and in the course of two or three years the mixture will tend to breed closer and closer to the desired type. A promising early mixture has been obtained in this way at Pusa which will soon be ready for a trial on an estate scale. There is, however, no reason why every planter could not begin work himself on these lines and develop an early mixture suited to the condition of his estate. About a hundred or two early flowering plants should be selected from the ordinary mixed crop and labelled. The seed of these should be mixed and sown the following August on a field scale and all late and unsuitable plants destroyed. It is more than probable that such a mixture, besides giving more indigo will also prove considerably more resistant to wilt than the present Bihar crop. We should not be surprised to find that this method, rough and ready as it is, will give better results than either of the two remaining methods which will now be described.

(2) Selection of single early types. The only difference between this method and that just described is concerned with the number of original parent plants. In the present case, the selection is started from one plant. The choice is made after observing the produce of about fifty promising individuals grown in lines side by side. The two best cart-fillers are selected, all late and weak plants eliminated and the seed of each is sown separately on a large scale. Every year the process is repeated and most of the aberrant types removed before flowering. Any late plants which have escaped are

destroyed later on and in this way the selection is kept as near to type as possible. As soon as enough seed has been obtained, the two best single selections are tried on an estate scale. Two of such selections (types 11 and 15) are now being tried on the Dholi estate, care being taken to grow the seed of each in fields about two miles apart. Although these types are rapid growers and show considerable promise they are not likely to prove such good cart-fillers as the selection from the mixed early types. A mixture is likely to make the best use of the available space both above and below ground, by the interlocking of the branches and roots. The individuals of a single type get into each other's way much more than those constituting a mixture.

(3) Chemical selection. The success which has attended chemical selection in the case of the sugar beet is one of the reasons why both planters and investigators have hoped for similar results in Java indigo. The circumstances of the two cases, however, are widely different. While we consider that an attempt should be made to improve Java indigo by chemical methods, nevertheless we feel that planters should be prepared if not for actual failure at any rate for somewhat meagre results. The difficulties which attend the application of this method to indigo under Bihar conditions are considerable. In the first place, the plants likely to contain the highest *indican* will probably turn out to be late, deep-rooting sorts liable to wilt. The early, rapidly-growing types seem to be the most desirable kinds to grow and chemical selection ought only to be applied to these forms, at any rate at the beginning. In the second place, the chemically selected parents will have to be grown under nets and allowed to cross among each other by means of relays of pollen-free bees introduced into the cages. In the third place, the time available for analysing the parents is very small as the process must be completed before flowering begins. Unless the range in *indican* content of the individuals which remain after all unsuitable plants have been removed is considerable, chemical selection becomes impossible. We know that the individuals of a mixed crop vary widely in *indican* content. We do not know the range among the members of an early type left after the weak and unsuitable individuals have been removed. Chemical selection does not arise until a wilt-resistant type of Java indigo has been selected and tested on the estates. Once this has been obtained, an attempt can be made to improve it by chemical selection.

It must not be forgotten that a good deal of work was done by Bergtheil and Parnell at Sirsiah on the improvement of the Java crop by chemical selection. This is described in the last Sirsiah Report. A set

of seeds of the selected plants, which had been isolated on account of their high *indican* content, was handed over to us when the Indigo Research Station was closed. These seeds were sown at Pusa where they proved to be slow-growing, deep-rooted types. They were destroyed by wilt and did not set any seed. Side by side, the early, rapidly-growing Java selections grew vigorously.

It is well to bear in mind when considering the question of chemical selection that the Bihar method of raising seed from the Java indigo grown for leaf amounted, to all intents and purposes, to the selection of plants high in *indican*. By this process, the late-flowering, deep-rooting types were preserved and the early forms suppressed. The result of this unconscious chemical selection was to bring the natural indigo industry to the verge of ruin.

2. Sumatrana indigo.

The improvement of Sumatrana indigo by selection is likely to prove even more difficult than that of the Java crop. Sumatrana does not yield so much seed as Java when grown under Bihar conditions.

The general methods of pollination and fertilization in Sumatrana closely resemble those already described in the case of Java indigo. The details with regard to the structure of the flower, the method of pollination and the infrequency of setting under nets are very similar in both species.

The methods of selection possible in Sumatrana are very much those above described in detail in the case of the Java plant. There is, however, less range in form in the case of the Cawnpore plant—the type which appears to be the most favourable selection ground. The indigos from North-West India are generally agreed to be hardly worth growing in Bihar. The Madras type is more promising both from its branched habit and higher *indican* content but it does not grow well under Bihar conditions. As it matures later than the Cawnpore plant, its root-system is deeper and in this may probably be found the reason for its unsuitability for general cultivation in Bihar.

In 1914, a small quantity of Madras Sumatrana was obtained from the Cuddapah District. This type was tried at the suggestion of Professor A. G. Perkin, F.R.S., who found in England that it contained more *indican* than Bihar Sumatrana. It was sown in August for seed by the side of the ordinary Cawnpore Sumatrana. Although later in flowering, the Madras type grew and branched exceedingly well and appeared to be very promising. Enough seed was then obtained from Madras for a full vat test on the Dholi estate the following year. The result was not promising. The yield of indigo to every 100 maunds of

plant was very satisfactory and better than the Cawnpore plant. The produce per acre, however, was disappointing and the crop did not grow well under monsoon conditions. The Madras type being deep-rooted probably requires better soil-aeration than is possible under Bihar conditions. The result, however, is of interest. It supports the view that lateness, deep-rooting and high *indican* content go together and that this combination is of no value in the Bihar alluvium.

Should it be found possible by selection to improve the Cawnpore plant, the difficulty of the seed-supply will still remain to be overcome. Sumatrana seed is not grown in Bihar and as far as can be seen at present it is likely that it will be cheaper to import seed from the Cawnpore region than to grow it locally. What will be the fate of an improved Sumatrana when grown by cultivators who cannot be supervised? The chances are that it would speedily become mixed with country seed and therefore lost to the Bihar industry. Until some efficient means of controlling the production of Sumatrana seed has been devised it seems hardly worth while to expend the labour needed for selection work in this crop.

One line of investigation however must be kept in view namely, the possibility of crossing a high yielding Java type with a good strain of Cawnpore Sumatrana. The object would be to evolve a new type of Java with a shallower root-system and more rapid growth for Bihar conditions. Such an improvement depends on whether Java and Sumatrana can be crossed. Attempts have been made in this direction by two of the assistants at Pusa but without success. As soon as opportunity permits, we propose to examine this matter ourselves.

VII. INDIRECT METHODS OF IMPROVING INDIGO.

Apart from the well known value of *seeth* in Bihar agriculture and the fact that we are dealing with a leguminous plant, there is one aspect of indigo cultivation to which insufficient attention has been paid. This is the place of indigo, particularly of Java indigo, in the rotation. The deep root-system of this crop acts like *rahar* and is a most efficient subsoil plough for the Bihar alluvium. It not only tends to conserve the supply of organic matter but also opens up the sub-soil and helps to keep the land in condition. If the cultivation of Java indigo were given up on the estates, planters would have to place their high lands periodically under *rahar*, the value of the seed of which is small. The advantage to rice of a previous crop of Sumatrana is recognized and several planters have observed the improvement in the rice which results from this rotation.

In the second indigo report, reference was made to two indirect methods of improving the indigo industry, namely, the provision of a more valuable cover crop for Java indigo and the better utilization of *seeth*. Further work has been done in both these directions.

Cover crops. On certain soils in Bihar, it appears desirable to check the development of the Java crop during the cold weather and to begin the hot season with a somewhat late plant. This is accomplished by growing a cover crop such as wheat which not only checks the indigo and provides revenue but also keeps down weeds. Possibly on very strong soils which hold water well and in localities where the conditions are such that little burning takes place in the hot weather, it may be an advantage to grow a pure indigo crop and to force on growth for early manufacture so as to secure a second and possibly a third crop while *mahai* is still possible. Whether or not a cover crop is desirable in the case of Java indigo is likely to be settled by local experience. The danger of a cover-crop is undoubtedly to be found in the possible interference with sufficient light for the young indigo. If the cover-crop is too rank, too much light will be cut off and the indigo will suffer. This is likely to happen with any kind of wheat (unless sown thinly) on strong soils.

In cases where a cover crop is found desirable there can be no question that a rapidly maturing wheat with little foliage like Pusa 4 is suitable for the purpose. For some years on the Dholi estate, good crops of this wheat have been grown with Java indigo and provided the stubbles are thoroughly harrowed afterwards, the succeeding indigo crops develop well in an average year. The harrowing, however, is essential and it is best to get this done immediately the wheat is cut and the surface soil is still soft and moist.

The value to the planter of a *rabi* cover crop like wheat depends partly on the existence of a ready market. Fortunately Pusa 4 is an early kind with good grain qualities and therefore likely to find favour in the Calcutta mills. To test this, a full scale milling test was arranged last April at theHooghly Flour Mills which are managed by Messrs. Shaw, Wallace & Co. The parcel of 350 maunds milled was grown partly on the Benipore estate and partly at Dholi. The Manager of the Hooghly Mills (Mr. H. G. Taylor) has kindly sent the following report for publication (Letter dated Ramkristopore, June 24th, 1916) :—

" Both lots of wheat received were quite up to the standard of the sample sent from Pusa, clean and of uniform grade, and contained not more than one and a half per cent. refraction. I had a test taken of

the natural moisture content and this worked out at 11 per cent, this high percentage being due to the more humid atmospheric conditions then prevailing.

I find Pusa 4 is capable of absorbing water in larger quantity than is the case with the ordinary varieties we have to deal with and this appreciably enhances its value. During the milling process, the semolina and middlings separated very freely from the bran, and the yield of the former was much higher than is ordinarily possible, the quality was also correspondingly high.

In the actual reduction of middlings to flour there was an entire absence of what we describe as " wooliness " or " softness " with the result that the dress out of the centrifugals was very free, the flour quite lively to the touch, and the separations all that could be desired.

I presumed from the appearance of the wheat that the bran percentage would be low and this turned out to be the case for it was 3 per cent. below our normal. With the experience gained, and a larger quantity of this wheat to handle, I believe a still lower bran percentage would be possible.

On testing the flour by the Pekar test it turned out of a greyish white (the native of India prefers his flour to have a slightly yellow tint); the colour may improve by an additional moisture content. Under the doughing test, the flour showed great tenacity thus indicating the presence of gluten of high quality and quantity; the following figures show the percentages of gluten content, wet and dry, as compared with our ordinary quality of flour.

	Wet.	Dry.
Pusa	42·3	15·75
Ordinary	32·6	11·1

The drying was carried out in a Hearson electric oven at a temperature of 100°C. for five hours.

The last and most conclusive test of all has been the baking test; it is in consequence of an unsatisfactory baking test carried out a fortnight ago that the presentation of this report has been delayed, and this result was due to the incompetence of the baker I had then engaged. However, I have now a good man, and he has just turned out a batch of the finest bread I have ever seen in India; the loaves are equal in appearance to the Manitoba and Pusa 4, illustrated in your " Milling and baking qualities of Indian wheats " and is in decided contrast to the corresponding loaves made from our ordinary superfine, although that is also of very high quality. The texture of the bread is very uniform and it possesses a distinctly agreeable flavour; my baker speaks highly of it and states that it is the best flour he has ever handled.

I have now concluded my report and trust that I have made myself sufficiently clear and intelligible. If there are any other points you would like information upon please do not hesitate to write and I shall be most willing to assist you to the best of my ability."

It will be seen that the results of the trial are very satisfactory and that the Calcutta Mills are likely to buy up any quantity of this wheat produced in North Bihar. There is bound to be a considerable demand for Pusa 4 for seed purposes for certain tracts in Central India and in the United Provinces where this wheat is being taken up by the cultivators. The planters growing Pusa 4 in bulk will therefore have no difficulty in disposing of this wheat at remunerative prices.

The efficiency of seeth. As is well known, *seeth* is an excellent manure for tobacco. Its value, however, depends on its power of aerating the soil as well as on its chemical composition. Evidence has been obtained at Pusa that small pieces of tile (*thikra*) when added to tobacco lands also act as an efficient aerating agent. During the past year it was found that *sanai* used as a green-manure on a *thikra* plot gave twenty-four maunds of cured cigarette tobacco to the acre which fetched fifteen rupees a maund. It is clear that if the experiments in progress prove that it will pay to dress portions of the factory *zerats* with *thikra*, such lands will need much less *seeth* than is now customary to apply. The experiments on this subject have now reached an estate scale and the results will be published as they accumulate.

QUETTA,
August 8th, 1916.

Sugar and the Sugarcane in the Gurdaspur District

[*Received for publication on 10th October, 1916.*]

CHAPTER I.

THE GURDASPUR DISTRICT AND THE INDIGENOUS METHODS OF CANE-GROWING PRACTISED THERE.

1. The climate.

The Gurdaspur District which is some 1,826 square miles in extent with a population in 1911 of 836,771, comprises the submontane and upper plains portions of the Bari Doab* lying between the Bias and Ravi rivers, and extending across the latter into the submontane tract of the Rachna Doab between the Ravi and the Chenab. Its proximity to the foot-hills of the Himalaya secures for this district a far more generous rainfall than is the case with the greater part of the arid province of which it is a part, and it is largely owing to the abundance of water so secured that Gurdaspur has taken the first rank in cane cultivation in the Punjab.

The district enjoys a rainfall of from 24 to 50 inches of water per annum. This is not incomparable with that falling on the cane lands of Hawaii, but in the latter case there is a moist island climate of more or less equable temperature—in spite of this the amount of water received by the crop during 17 months is according to Deerr 27″ of rain water and 76″ irrigation water or 103″ in all or about 1,000 lb. of water per lb of sugar produced.

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* Doab means the space lying between two rivers; *do* (Persian) two and *ab* water.

O'Shaughnessy estimates the irrigation duty of water in Hawaii to be 134″ per annum not counting natural rainfall. According to Tiemann, in Egypt which is much more comparable to the Punjab climatically, cane receives about 95″ of irrigation water between the month of February (planting) and the end of October (when the harvesting commences).

We should expect, therefore, to find very little *barani** cane in the Punjab or indeed throughout North-West India.

TABLE I.

Rainfall in Gurdaspur for past 8 years.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total for the year (in inches)
1908 .	1·32	1·25	0·00	2·62	0·00	1·29	8·18	12·87	6·08	0·00	0·22	0·21	33·94
1909 .	1·16	1·51	0·00	1·87	0·00	1·38	6·34	15·47	9·10	0·16	0·00	2·32	39·31
1910 .	2·18	0·26	0·20	0·06	0·00	8·13	6·04	22·33	1·82	0·00	0·20	0·00	41·22
1911 .	8·95	0·39	8·41	0·24	0·00	3·39	1·83	6·50	2·23	0·24	1·75	0·00	33·93
1912 .	4·03	0·07	0·24	0·91	0·26	0·03	9·66	11·76	0·41	0·00	0·80	0·04	28·21
1913 .	0·50	2·91	1·76	0·00	1·18	4·29	6·62	9·26	0·00	0·03	0·00	1·03	27·58
1914 .	1·16	1·99	1·52	3·06	1·57	4·08	30·04	2·47	4·65	2·99	0·60	1·77	55·90
1915 .	2·22	3·94	2·48	0·35	0·00	0·55	2·76	3·88	3·36	2·04	0·00	0·07	21·65

In Gurdaspur the temperature frequently falls below freezing point (32°F.) during the months of December and January, and this causes an enormous amount of damage to the crop as well as constituting one of the most serious obstacles in its improvement. I shall show in Chapter III how this affects the cane and how, in the introduction of new varieties, the selection of hardy types is of prime importance.

2. The soil.

The soil of the district varies considerably in texture as we pass from the rivers towards the high-lying portions of the Doab and from the Doab towards the foot-hills. On the whole, it is a fairly light soil,

* *Barani* means grown by rainfall alone, that is, no water either from canal or wells is used for irrigating the crop ; see Tables V and VI.

like the bulk of the Punjab alluvium, but not too light to provide an excellent substratum for the growth of both wheat and cane, two of the most important crops grown in the district. The high-lying ridges of the Doab appear to owe their fertility in a large measure to the excellent drainage which they possess, for good drainage is one of the most important factors in the successful ripening of sugarcane. It is probable that this is one of the principal reasons why cane does so well in these parts, for as we proceed towards the rivers the quality of the cane falls off in spite of the richness of the land. Generally speaking, sugarcane is a plant which in its growth demands large quantities of water, and therefore naturally prefers a soil of water-retaining power like clay. In such soils, irrigation is not so frequent or so necessary, but in the Gurdaspur soils we have to deal with a more porous type, and the water supply of the plant has to be maintained in an artificial manner if the rainfall is not frequent and plentiful. This is accomplished by irrigation from both wells and from canals. The effect of starving the plant of water during its growth is to produce a thin woody cane ; while excess of water and lack of proper drainage retard ripening. The ideal soil, therefore, for cane growing would seem to be a stiff heavy soil underlaid with sand. Throughout the Punjab alluvium we find such soils representing old clay pockets—the result of back waters and still ponds, when the soils were in course of being deposited. These beds may vary from a few inches in depth to many feet, but underneath all sand is invariably found. Such is the nature of the richest farm land, not only in this district but throughout the Province where sufficient water can be obtained to secure healthy plant growth. Too often, however, the water supply is deficient, and these clay beds then cause the accumulation of saline matter on the surface, which, barren of all vegetation, and showing as white excrescence on the surface, has the appearance of some loathsome disease of the land.

Cane appears to grow almost equally well in all soils, if it receives the water and manures necessary for its even and healthy growth, and if the temperature is suitable. Calcareous soils are generally considered to be among the best for cane growing, for such soils yield a rich and easily worked juice. The composition of the soils of the Hawaiian archipelago is of particular interest to the cane grower by reason of the exceptionally high returns obtained there. A study of these soils reveals the fact that they contain large quantities of lime and iron, smaller quantities of potash, and considerable quantities of phosphates in the form of apatite. The sedimentary soils are among the most productive in the island and are often of great depth.

The Gurdaspur soils are for the most part (Table III) deficient in the manurial constituents of lime and nitrogen. The exhausted condition of these soils for sugarcane cultivation is particularly emphasized by the small amount of lime as compared with the amount of magnesia present, and indicates the need of manuring combined with a much deeper cultivation than is at present given.

TABLE II.

Mechanical analysis of soils from the Gurdaspur District, 1914.

Grams per 100 grams of soil.

Source of soil	Stones and gravel	Soluble matters and hygroscopic moisture	Fine gravel	Coarse sand	Fine sand	Silt	Fine silt	Clay
Sugarcane soil from Batala	1·45	4·13	1·14	25·96	28·10	16·10	12·71	10·23
Sugarcane soil from Harchowal (Batala)	..	1·90	0·25	23·00	22·91	20·01	19·93	15·60
Sugarcane soil from Bham (Batala)	1·81	1·60	0·41	23·87	32·30	17·92	12·99	12·48
Sugarcane soil from Chhina (Gurdaspur)	..	2·35	0·48	8·13	19·02	27·45	26·02	12·96
Sugarcane soil from Gurdashangal (Gurdaspur)	..	2·28	0·23	14·30	28·84	26·82	18·20	9·28
Sugarcane soil from Mári Buchián (Batala)	..	1·65	0·11	23·70	27·23	25·44	12·94	7·36
Experimental Farm, Gurdaspur	..	1·19	0·24	38·29	19·92	17·24	13·60	6·40
Experimental Farm, Gurdaspur	..	1·20	0·16	40·93	21·52	16·85	12·24	5·92
Experimental Farm, Gurdaspur	..	0·94	0·11	28·07	28·21	20·47	13·36	6·40
Experimental Farm, Gurdaspur	..	0·95	0·24	32·94	24·30	20·08	13·04	6·40
Experimental Farm, Gurdaspur	..	0·87	0·16	35·56	24·47	17·98	12·56	6·32
Experimental Farm, Gurdaspur	..	0·86	0·29	40·85	19·75	16·36	14·96	7·33

TABLE III.

Chemical composition of the soils referred to in Table II. Sugarcane soils from the Gurdaspur District, 1914.

Sources of the soil	Insoluble in boiling hydrochloric acid, silica, silicates, etc.	Al_2O_3 and Fe_2O_3	CaO	MgO	SO_3	Nitrogen (N)	Total potash as K_2O	Available K_2O	Total P_2O_5.	Available P_2O_5
			Grams per 100 grams of soil.							
Sugarcane soil from Batala	84·33	8·08	0·90	1·03	0·06	0·063	0·351	0·050	0·449	0·147
Sugarcane soil from Harchowal (Batala)	83·44	9·01	0·28	0·97	0·05	0·058	0·304	0·032	0·435	0·082
Sugarcane soil from Bham (Batala)	88·63	6·37	0·27	0·82	0·04	0·052	0·292	0·027	0·486	0·112
Sugarcane soil from Chhina (Gurdaspur)	82·98	10·84	0·29	0·62	0·07	0·078	0·314	0·023	0·409	0·038
Sugarcane soil from Gurdashangal (Gurdaspur)	86·15	8·47	0·29	1·04	0·07	0·075	0·336	0·023	0·438	0·066
Sugarcane soil from Mári Buchián (Batala)	88·08	8·07	0·27	0·79	0·07	0·052	0·317	0·022	0·330	0·038
Experimental Farm, Gurdaspur	88·66	7·82	0·35	0·46	0·064	0·048	0·366	0·015	0·71	0·023
Experimental Farm, Gurdaspur	88·79	7·40	0·30	0·98	0·073	0·045	0·343	0·014	0·65	0·032
Experimental Farm, Gurdaspur	88·87	7·49	0·51	1·17	0·073	0·046	0·381	0·013	0·56	0·025
Experimental Farm, Gurdaspur	87·99	7·62	0·30	0·88	0·032	0·049	0·448	0·015	0·64	0·026
Experimental Farm, Gurdaspur	89·15	7·05	0·48	1·17	0·115	0·046	0·422	0·014	0·62	0·020
Experimental Farm, Gurdaspur	88·35	7·23	0·43	1·23	0·068	0·048	0·443	0·017	0·82	0·025

3. Distribution of the varieties of canes grown in the district.

The greater portion of the cane produced in the district is grown in the tahsils* of Batala and Gurdaspur, and it is generally considered among the farming classes that the Batala tahsil is the more favourably situated for the cultivation of this crop and that the average out-turn per acre is higher there than in any other part of the district. Generally speaking, the cane falls off in quantity and out-turn as we approach the foot-hills, for whereas the out-turn of raw sugar per acre is about 25 maunds in Batala, in Pathankot it is only about 9½ maunds.†

In the following table (Table IV) is shown the distribution of cane throughout the Gurdaspur District in the year 1913. In the same table are shown the different classes of land on which the crop was grown, *viz.*, *chahi*, *nahri*, and *barani*, and sub-divisions of these.

* Tahsil is a division of the district for administrative purposes It is under the charge of a superior official (Indian) called a tahsildar, who is a magistrate of the second class.

† The maund referred to in the Bulletin is the standard measure of weight in North-West India—it is approximately equal to 82 lb. avoirdupois.

1 maund = 40 seers.

1 ton = 27·3 maunds.

TABLE

Sugarcane cultivation in Gurdaspur

Description of crop	Tahsil Batala						Tahsil Gurdaspur					
	Bet Ravi	Maira Kiran	Nahri Sharqi	Nahri Gharbi	Bangar	Total of Tahsil	Bet Ravi	Maira Kiran	Nahri	Bangar	Bet Beas	Total of Tahsil
1. Chahi	1,182	2,431	623	2,767	4,904	11,907	278	1,901	1,894	1,123	14	5,210
	32	**88**	**13**	**58**	**188**	**379**	..	**34**	**42**	**37**	..	**113**
2. Chahi Nahri Zamindari	..	..	..	..	..	..	..	..	..	..	..	..
3. Nahri Zamindari	..	..	..	..	..	..	..	25	..	..	12	37
	..	..	..	..	..	..	..	..	..	..	**8**	**8**
4. Abi	21	89	2	5	1	118	1	27	11	14	1	54
	..	**3**	..	..	..	**3**	..	..	..	**1**	..	**1**
5. Sailab	240	82	645	5	..	972	1,861	..	..	..	1,158	3,019
	28	**7**	**27**	..	..	**62**	**119**	..	..	..	**169**	**288**
6. Barani (I)	57	10	17	19	38	141	698	1,147	683	447	263	3,238
	4	**2**	**8**	**2**	**14**	**30**	**58**	**62**	**38**	**35**	**37**	**230**
7. Shah Nahri	..	209	2,721	3,755	..	6,685	..	363	5,803	174	99	6,439
	..	..	**66**	**67**	..	**133**	..	**3**	**99**	**2**	**1**	**105**
8. Barani (II)	..	..	12	8	23	43	14	57	70	113	39	293
	..	..	**1**	..	**7**	**8**	..	**10**	**3**	**10**	**2**	**25**
9. Chahi Nahri	..	..	21	2	..	23	..	3	12	..	..	15
	..	..	**1**	..	..	**1**	..	..	..	..	..	..
10. Sailab Chhamb Mustaquil	..	..	..	..	..	..	..	781	165	..	850	1,796
	..	..	..	..	..	..	..	**37**	**2**	..	**100**	**139**
11. Sailab Chhamb Ghair Mustaquil	..	..	..	..	..	..	..	..	..	..	213	213
	..	..	..	..	..	..	..	..	..	..	**76**	**76**
12. Barani (III)	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..
TOTAL	1,500	2,821	4,041	6,561	4,966	19,889	2,852	4,304	8,638	1,871	2,649	20,314
	64	**100**	**116**	**127**	**209**	**616**	**177**	**146**	**184**	**85**	**393**	**985**

1. Chahi=
2. Chahi Nahri Zamindari=Irrigated
3. Nahri Zamindari=
4. Abi=Irrigated from tank or
5. Sailab=Land moistened by the
6. Barani=
7. Shah Nahri=Irrigated
10. Sailab Chhamb Mustaquil=Permanent
11. Sailab Chhamb Ghair Mustaquil=Sailab fluctuating—not permanently moistened or flooded by lake, but flooded or

N.B.—Figures in ordinary type indicate the area in acres under matured crop, while figures in heavy type indicate the

IV

District, 1913-14, showing how irrigated.

Tahsil Pathankot							Tahsil Shakargarh					
Andhar	Bet Ravi	Pathan-ti	Shah Nahr	Kandhi	Pahari	Total of Tahsil	Bharrari	Paintla	Bet Ravi	Darp	Total of Tahsil	Total of the District
..	1	..	1	10	..	12	26	5	7	1,330	1,368	18,497
..	..	..	..	..	..	..	..	..	..	79	79	571
..	..	..	..	..	..	..	..	..	..	..	..	..
101	15	141	9	..	178	444	..	..	..	..	..	481
5	2	11	..	..	13	31	..	..	..	..	..	39
..	..	..	..	..	..	..	..	1	..	4	5	177
..	..	..	..	..	..	..	..	..	..	..	..	4
705	446	236	38	120	..	1,545	872	356	2,127	686	4,041	9,577
93	46	41	10	20	..	210	65	27	242	75	409	969
493	699	296	639	102	50	2,279	796	1,342	435	1,295	3,868	9,526
39	37	20	1	10	4	141	127	77	29	229	462	863
..	..	32	161	13	..	206	..	..	..	..	..	13,330
..	..	1	8	4	..	13	..	..	..	..	..	251
..	..	..	..	49	74	123	80	138	26	125	369	828
..	..	..	..	10	19	29	15	13	6	28	62	124
..	..	..	..	..	..	..	..	..	..	..	..	38
..	..	..	..	..	..	..	..	..	..	..	..	1
..	..	..	..	..	..	..	..	..	..	..	..	1,796
..	..	..	..	..	..	..	..	..	..	..	..	139
..	..	..	..	..	..	..	..	..	..	..	..	213
..	..	..	..	..	..	..	..	..	..	..	..	76
..	..	..	..	..	4	4	12	..	..	2	14	18
..	..	..	..	..	1	1	2	..	..	..	2	3
1,299	1,161	705	848	294	396	4,613	1,786	1,842	2,595	3,442	9,665	54,481
137	85	73	49	44	37	425	209	117	277	411	1,014	3,040

Well irrigated.
both from private works and from wells.
Irrigated from private works.
pond by human or bullock agency.
action of river or lake or flooded by river.
Depending upon rain water.
from Government works.
Sailab—permanently moistened or flooded by lake.
only moistened when the water in the lake is at a high level.
area that did not mature ; and the sum of the two gives the total area sown.

The different varieties of cane found in the district will be described in detail in Chapter III. These are *Katha*, *Dhaulu*, *Teru* or *Tereru*, *Kahu*, and *Kansar*.

Their distribution is as follows :—

Batala Tahsil. In the western and eastern canal circles on canal-irrigated lands, *Dhaulu* is the predominating variety in this tahsil. It yields well on land that is not too light in texture and where the water supply is good. On the lighter sandy soils *Katha* is usually grown in preference to *Dhaulu*. *Teru* or *Tereru*—a cane similar to *Dhaulu* in appearance but having ivory markings on the stem—is grown on the same class of land as *Dhaulu*. It is not as popular with zemindars* as *Dhaulu* cane but is thought to be slightly inferior. The quality of the *gur* and the yield from *Dhaulu* is higher than from *Katha*. In some villages in the western canal circle near the main canal, there is grown a thicker variety known as *Kahu-Katha* or *Kansar*. This cane is of the *Katha* type and is midway in thickness between *Dhaulu* and *Kahu*. It is similar in colour to *Katha*, and it requires very moist conditions for its successful growth, as it has a tendency to form a dry pith in drought. It ripens later than *Dhaulu* and earlier than *Kahu*. It gives heavier yields than *Dhaulu*—a good crop yielding under favourable conditions as much as from 40 to 60 maunds of raw sugar (*gur*) per acre. This variety is only grown extensively in the neighbourhood of Dabanwala. In this tract about 12 years ago, very large areas of *Kahu* cane were grown and from information obtained locally it appears that *Kahu* was practically the only variety found over a tract of country of 25 square miles in extent (see also *Gurdaspur Gazetteer*, 1891-92, page 95). At the present time, however, there is practically no *Kahu* to be found in this tract, its place having been taken by *Kansar* and *Dhaulu*. The information given by the villagers is that 13 years ago this variety was completely wiped out by red rot. This is probably correct, for in the season 1911-12 the farm crop of *Kahu* at the Experimental Station at Gurdaspur was so severely attacked by red rot at an early stage of its growth that the entire crop had to be destroyed. *Kahu*, owing partly to its susceptibility to red rot and frost and partly to the large amount of water it requires, is not being extensively grown, and from season to season the area under this cane varies considerably.

In the eastern canal circle on canal-irrigated land in the neighbourhood of Harchowal, this variety has for the past few years been again coming into favour, and in 1913 the area under *Kahu* was considerable, but this is unlikely to last, for the cultivation of this variety is more or

* Zemindar = a peasant farmer.

less a gamble against the climate ; if the conditions are favourable heavy out-turns of superior quality of raw sugar (*shakkar*) are obtained, and yields as high as from 60 to 80 maunds to the acre. It ripens late, however, towards the end of January, and consequently is more at the mercy of a fall in temperature than the early maturing varieties of sugarcane. *Kahu*, being a soft cane, is also grown for chewing.

There is also a considerable area of cane grown on well-irrigated lands in the eastern and western circles. *Dhaulu* and *Katha* are the varieties chiefly grown on them, *Dhaulu* on the heavier loams where the water supply is good, and *Katha* on the inferior lands. The *sailab* (*loc. cit.*) canes are practically all *Katha*, as this variety is hardy and is better adapted to stand the water-logged conditions of inundative irrigation. The drainage of these *sailab* lands would add considerably to the available area for the growth of better varieties of cane in this district, and should be one of the lines of agricultural improvement to be followed in the future.

In the Bangar circle, the cane is practically all well-irrigated and the variety most grown, especially round Batala, is *Katha*. The reason for this is that this cane requires less irrigation and gives better yields on the light soils of this tract than does *Dhaulu*. The yield on well-irrigated land is said to be higher than when grown under canal irrigation, but, from the appearance of the crops in this very fertile tract, we should say this difference must be very small. It is known that in the Punjab the irrigation duty of canal water is only about one-third of that of well water. It is also known that in dry years when the supply of canal water is reduced, the out-turn of wheat increases. The difference is probably due to the better cultivation given for well irrigation, and the greater precautions taken to conserve the soil moisture by preparing a good mulch.

In the Mairu Kiran circle the land is not so suitable on the whole for cane cultivation, as the soil there tends to become too light. However, considerable areas of cane are grown under well irrigation, *Katha* and *Dhaulu* preponderating with occasional patches of *Kansar*.

In the Bet* Ravi circle, well-irrigated cane is also grown, but very little under inundative irrigation. *Barani* (*loc. cit.*) cane is hardly ever found in the Batala tahsil, though the cultivators state that before the construction of the Upper Bari Doab Canal, there were considerable areas of cane grown on *barani* lands.

Gurdaspur Tahsil. What has been said with regard to the suitability of the different varieties of cane for different soils and systems of irrigation in Batala applies equally to Gurdaspur and the other tahsils of the district.

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* Land adjoining rivers and liable to flooding when the rivers rise is known as *bet*. It is generally fairly well drained.

In the Gurdaspur tahsil the area under cane is about the same, or a little less than that in Batala. Rice cultivation however comes into competition with sugarcane in this tahsil, as may be seen from Tables V and VI. In addition to that grown under well and canal irrigation, a considerable amount of cane is grown under *barani* and *sailab* conditions, though the area under *barani* cultivation has declined during recent years.

The varieties found are *Dhaulu* on the best lands and *Katha* on the inferior soils. There is an inferior type of wet raw sugar termed *leb* produced from the cane grown near the Beas, and to a less extent in the Ravi Bet. *Katha* is the only variety of cane grown in these tracts and it also predominates in the *barani* lands. The yields of cane in the south of this tahsil, where the best soils are to be found, are as good as those of Batala, but, as we go further north and east, the crops get poorer and the yields fall off. It is interesting to note that the quality of raw sugar from a *barani* crop is as a rule superior to that grown on irrigation. This is in fact due to the better drainage enjoyed by *barani* lands, but it is also due in large measure to the fact that the land in this case gets a year's fallow before sowing the cane, thus endorsing what we have said above about the exhausted condition of these soils.

TABLE V.

The area under sugarcane, rice and cotton in acres together with the rainfall in the Gurdaspur Tahsil of the Gurdaspur District.

Year	Total rainfall	Rainfall, January to May	Area under rice	Area under cotton	Total area under sugarcane	Sugarcane area					Price of Gur (per maund of 82 lb.) in rupees.
						Chahi	Nahri and Chahi Barani	Abi	Sailab	Barani	
1901	33·22	11·05	19,092	2,380	16,783	4,448	4,275	224	3,314	4,522	..
1902	19·46	2·96	18,713	2,910	17,766	5,873	4,856	61	4,373	2,603	..
1903	?	7·09	17,309	2,195	17,552	4,953	5,158	43	4,258	3,140	..
1904	23·48	7·99	12,715	2,723	16,729	4,462	4,343	55	3,614	4,255	..
1905	16·69	7·75	15,300	4,956	9,149	2,587	1,994	13	2,454	2,101	..
1906	45·12	8·11	13,171	3,225	16,913	4,929	5,306	29	3,721	2,928	7·07
1907	32·47	18·9	11,615	2,774	15,662	4,237	4,707	249	3,138	3,331	4·31
1908	33·94	5·19	14,870	3,552	18,491	4,922	5,230	59	4,824	3,456	5·58
1909	39·31	4·54	13,974	2,545	21,712	5,344	6,946	13	5,561	3,848	4·68
1910	41·22	2·70	13,611	1,634	20,208	4,578	6,179	63	5,084	4,304	4·18
1911	33·83	17·99	11,556	4,120	14,256	3,989	4,015	62	2,961	3,229	4·55
1912	28·21	5·51	14,151	3,507	18,602	4,998	5,929	48	4,510	3,117	5·94
1913	27·58	6·35	14,209	5,404	20,314	5,210	6,491	54	5,028	3,531	4·55

TABLE VI.

The area under sugarcane, rice and cotton in acres together with the rainfall in the Batala Tahsil of Gurdaspur District.

Year	Total rainfall in inches	Rainfall, January to May	Area under rice	Area under cotton	Total area under sugar-cane	Sugarcane Area					Rate of Gur, January to May, in seers per rupee	Price of Gur (or raw sugar) per maund in rupees
						Chahi	Nahri and Chahi Nahri	Abi	Sailab	Barani		
1901 .	22·55	8·11	7,051	5,233	18,192	12,430	3,150	370	1,050	1,192	..	..
1902 .	13·04	2·73	8,442	5,787	15,660	10,525	3,642	109	1,268	116	..	..
1903 .	40·26	5·91	8,520	4,052	18,438	10,933	6,024	108	983	390	..	
1904 .	25·28	8·17	7,316	5,208	17,155	11,035	4,554	125	675	766	..	..
1905 .	20·94	5·71	9,927	8,242	6,283	4,493	1,220	80	309	181	9·9	4·14
1906 .	27·85	6·76	8,595	4,910	15,399	10,308	4,064	83	750	194	6·9	5·94
1907 .	19·74	11·89	6,765	4,827	17,182	11,486	4,751	124	541	280	9·8	4·18
1908 .	32·42	4·28	9,854	5,638	17,692	10,289	5,888	85	1,010	420	8·5	4·82
1909 .	42·42	5·55	8,143	4,931	17,801	11,425	4,888	132	897	459	9·5	4·31
1910 .	31·40	2·18	8,838	4,957	19,614	12,157	6,110	145	820	382	10·0	4·10
1911 .	24·19	14·99	6,663	7,601	14,887	9,742	4,243	113	429	360	8·5	4·82
1912 .	25·27	5·72	9,661	5,901	20,803	12,912	6,754	93	837	207	7·1	5·77
1913 .	26·42	4·72	8,130	10,357	19,887	11,907	6,706	118	972	184	8·4	4·88

Shakargarh Tahsil. As we go further east nearer to the hills, the rainfall increases, and with it the area under *barani* cultivation naturally increases also.

The average rainfall for the four tahsils of the district for the past 26 years has been :—

	Inches
Pathankot	48·0
Shakargarh	38·4
Gurdaspur	31·7
Batala	30·8

In the Shakargarh tahsil, with the exception of 1,300 acres of well-irrigated cane in the Doab circle, the whole of the cane grown is either *barani* or *sailab*. *Katha* is the prevailing variety as we should expect though some *Dhaulu* is grown too. In this tahsil cotton is a severe competitor (see Table VII).

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TABLE VII.

The area under sugarcane, rice and cotton together with the rainfall in the Shakargarh Tahsil of the Gurdaspur District.

Year	Rainfall		Area under rice	Area under cotton	Total area under sugar-cane	Sugarcane Area				
	Total	January to May				Chahi	Nahri	Abi	Sailab	Barani
1901	23·89	10·67	5,547	13,598	9,969	1,311	..	2	3,960	4,696
1902	20·49	3 28	5,496	8,333	9,929	2,304	..	8	4,988	2,629
1903	..	7·58	5,932	10,349	11,500	1,615	..	1	5,222	4,662
1904	24·05	9·61	3,322	10,550	12,757	1,467	..	..	4,928	6,362
1905	29·71	8·43	3,157	6,743	9,070	1,018	..	2	4,503	3,547
1906	46·26	8·57	3,357	10,764	11,648	1,173	..	4	5,318	5,153
1907	20·40	14·23	834	8,058	9,835	1,193	..	38	4,397	4,207
1908	31·90	4·33	4,389	7,989	8,974	1,263	..	..	4,816	2,895
1909	36·25	6·15	5,122	8,315	13,073	1,333	..	10	5,323	6,407
1910	39·64	2·69	5,178	2,051	12,534	1,331	..	3	5,031	6,169
1911	29·25	18·20	2,724	7,823	8,613	877	..	14	3,737	3,985
1912	26·28	4·80	4,604	6,935	9,220	1,113	..	1	4,483	3,623
1913	29·98	6·14	5,083	10,324	9,665	1,368	..	5	4,041	4,251

The yields in the Darp circle are good, but not so high as on well-irrigated lands in the Gurdaspur and Batala tahsils.

Pathankot Tahsil. The less said about the cane crop in this tahsil the better. *Katha* is the only variety found there, and is very inferior to the cane grown elsewhere in the district. Nearly all the crops in this tahsil are either *barani* or *sailab*. The principal crop, as might be expected, is rice (see Table VIII).

TABLE VIII.

The area under sugarcane, rice and cotton in acres together with the rainfall in the Pathankot Tahsil of the Gurdaspur District.

Year	Total rainfall	Rainfall, January to May	Area under rice	Area under cotton	Total area under sugar-cane	Sugarcane Area			
						Chahi	Nahri Zamindari and Nahri	Sailab	Barani
1901	52·61	16·99	27,824	3,751	4,973	9	1,043	1,353	2,568
1902	20·71	2·50	27,500	2,461	4,876	13	1,304	1,588	1,971
1903	..	9·23	26,430	3,292	5,194	9	1,230	1,787	2,168
1904	27·25	7·36	25,763	4,411	4,970	6	948	1,625	2,391
1905	35·76	9·19	23,977	4,528	2,618	..	465	862	1,291
1906	66·36	12·57	24,772	4,714	4,195	2	1,004	1,402	1,787
1907	37·19	18·19	22,102	3,322	4,323	7	941	1,256	2,119
1908	52·78	7·23	26,231	3,922	5,005	9	1,079	1,593	2,324
1909	51·58	5·43	27,796	2,877	5,278	10	1,158	1,753	2,357
1910	49·71	4·58	27,181	1,419	4,799	16	1,120	1,656	2,007
1111	49·87	22·19	24,549	3,648	3,169	2	880	923	1,364
1912	[illegible]	9·01	26,182	3,842	4,660	11	1,049	1,473	2,127
1913	42·66	10·75	26,729	3,462	4,513	12	650	1,545	2,306

4. Preparation of the land.

The old system of cultivation in which the land was allowed to lie fallow for 16 months before the sowing of the cane, has died out with the introduction of canal irrigation, with the result that the quality and out-turn of *gur* is said to be inferior nowadays. This may be only the garrulous reference of the farmer to "the good old times," for we have very few records left about the raw sugar then grown. In a note on sugarcane in the Gurdaspur District in 1883 Col. Harcourt (*Papers relating to Sugar Cultivation in the Punjab*, Punjab Government Secretariat Press, Lahore, 29th December 1883, 292, page 20) estimates the average out-turn of cane per acre as 7 tons and 2 cwt. and of raw sugar (*gur*) as 24 maunds or over 17 cwt. This is not very different from that of the present day, and is, if anything, rather less.

I have often examined excellent *gur* and *shakkar* from canal-irrigated cane, and the real reason for the production of a dry light coloured *gur* is ripeness of the cane at the time of cutting. This can never be obtained in this tract if the cane has suffered any set-back during its growth, for the growing season is so short that the plant has not time to recover.

Fallowing the land is, and always has been, recognized in the district as necessary in good cane cultivation. As a rule, the preliminary preparation of the land, *i.e.*, ploughing, commences after the breaking of the monsoon in July. Ploughing and levelling with the *sohaga* * is continued up to the following March, as many as 30 to 50 ploughings being given. This extensive cultivation serves two purposes: (1) The accumulation of reserves of available plant food and (2) the conservation of soil moisture. Any system introduced to shorten this fallow period would have to include an adequate system of manuring as well as an increased water supply for this crop during the first few months of its growth. In building up a refining industry the economics of any method of shortening the fallowing system would need to be carefully gone into.

Under the existing conditions, the cane occupies the ground for from $1\frac{1}{2}$ to 2 years. The land comes under cultivation in July after the breaking of the rains—it is continued up to the following March. Consequently no *kharif* (summer crop) or *rabi* (winter) can be taken. The cane is planted at the end of March or the beginning of April and

*The *sohaga* is a beam of wood 6 or 7 feet long by 1 foot by 9 inches thick, made of a hard wood usually "shisham" (*Dalbergia Sissoo*) or "kikar" (*Acacia arabica*). It is fastened to the yoke and the oxen by ropes or chains attached to pegs at either end. In the use of this implement the driver often stands on the beam when driving the cattle to ensure a better packing of the soil. It serves to level land for irrigation purposes, as well as to consolidate the soil in the preparation of the seed bed.

remains in the ground until the following January. It thus occupies the ground for four agricultural seasons—2 *rabi* and 2 *kharif*.

5. Rotation followed.

(*a*) Sometimes the cane follows a *rabi* catch crop of *senji* (*Melilotus parviflora*) or *masàr*, lentil (*Ervum lens*). Such catch crops are usually sown with maize in the preceding summer. They are cut and fed to the cattle in January and February. After the reaping of the cane the land lies fallow until the succeeding autumn, when wheat is sown. This is a three-year rotation, and is practised largely in the best sugarcane tracts of Batala and Gurdaspur and on both well- and canal-irrigated lands. In this rotation the manure is applied as a rule to the maize only, though sometimes a little is also applied before sowing the cane.

(*b*) Where the cane follows a cold weather crop after a ten months fallow: this is not a very common rotation on well-irrigated lands. After the reaping of the cane in December and January, *chari* (*Sorghum vulgare*) and maize (*Zea Mays*) or cotton are sown in the months of May and July and May respectively.

(*c*) Rotation followed on *sailab* lands where there is an annual deposit of silt. Cane follows cane every year or is rotated with wheat.

It is interesting to compare these systems with those practised in other parts of the province.

In Amritsar, the adjoining district further west, cane is grown on land which has been lying fallow for a year after maize or cotton. The rotation (*a*) wheat, (*b*) cotton or maize, (*c*) fodder (*senji*) and (*d*) cane is also followed in this district. In the Lyallpur District, still further west, which was in the first place populated with colonists from the Sialkot, Jullundar and Gurdaspur districts, the systems of cultivation are much the same, *viz.*, (*a*) maize and *senji*, sugarcane, cotton, (*b*) cotton, surgarcane, (*c*) wheat, *toria* (*B. Campestris* var. *Dichotoma*), sugarcane.

In Ludhiana cane follows cotton or maize, the preparation of the land being done during the *rabi* season. The rotation is as follows :—

(*a*) Cotton or maize, (*b*) cane, (*c*) fallow or sometimes barley, (*d*) cotton or maize and (*e*) wheat or barley. In Karnal and Delhi the commonest rotation is :

(*i*) (*a*) Sugarcane, (*b*) cotton and *methi* (*Trigonella Fœnum-Græcum*, Linn.) as a fodder.

(*ii*) (*a*) Maize and *moth* (*Phaseolus aconitifolius*), (*b*) sugarcane, (*c*) cotton.

6. Manuring.

In the first rotation mentioned for the Gurdaspur District, namely, (*a*) maize and *senji*, (*b*) cane, and (*c*) wheat, the maize crop usually gets

manure at the rate of about 360 to 390 maunds per acre (13·2 to 14·3 tons). The residue of this, together with the *senji* stubble, just leaves the land rich enough for sugarcane. The zemindars are very careful not to overmanure the cane crop as this leads to a falling off in the quality of the *gur*. This has not yet been fully investigated, and a careful study of this problem will certainly repay the scientific agriculturist. It appears as if the limit has been reached for the indigenous canes with the present plough. The season is short, and excessive manuring will merely result in promoting vegetative growth and lengthening the growing period, thus giving a large green and unripe cane at harvest time.[1] The stimulation of the crop should be given for the most parts in the initial stages of the growing period, and to render this more effective a deeper-rooted crop must be induced by deeper cultivation and by giving the young plant an adequate water supply.

The value of *senji* (*Melilotus parviflora*) lies in the conservation of soil nitrogen effected by this crop : as much as 21 lb. of fixed nitrogen per acre has been recorded at Lyallpur as a result of the growth of this plant. It occupies the ground for nearly 5 months.

In the two other rotations followed in this district the manure is applied directly to the cane, about the same quantity per acre being used. In this case only well rotted and fully ripe manure is applied, for fresh manure not only results in a retardation in development but also attracts white ants which damage the sets. In this system the manure is applied in February a week or two before sowing the cane. Manure is seldom purchased by the farmer but its price when sold is from 4 to 6 annas per cart-load (¾ ton). Near Batala as much as 12 annas or 1 rupee is often paid, but this is only for the cultivation of thick *Pounda* cane, a valuable garden crop sold locally for chewing.

The quantity of manure applied to sugarcane in other parts of the Province does not differ much from that above quoted for Gurdaspur. In 1883 Harcourt (*loc. cit.*) in a report to the Punjab Government on cane cultivation in the Gurdaspur District states that manure is applied at the rate of 21 tons per acre at a cost of Rs. 15, but he makes no mention of the type of cane for which this quantity is used, and most probably refers to the *Pounda* variety grown in the Batala tahsil. In the Deccan, Keatinge (Bombay Government Report, 1913) reports that as much as Rs. 180 per acre is spent in manuring for *Pounda* cane and the out-turn is about 36 tons per acre. But in the Deccan the climate places little or no restriction on the length of the growing period.

It is impossible to make any comparison of the manure rates or system here practised with that of other parts of India or of other sugarcane-

[1] *Cf.* Taylor, C. S. *Pusa Agri. Res. Inst. Bull. no. 37.*

growing countries. In the cane-growing countries where modern refining industries exist, artificial manures are almost entirely used, and the requirements of the soil have in each case to be worked out experimentally. Exactly the same applies to the sugar industry in the Punjab. At the present time cane growing both in the Gurdaspur District and in the Province is a zemindari industry of very low grade and only animal refuse and rotations can therefore enter into any feasible system of manuring, owing to the high prices of artificials and their unknown value to both the local farmer and the scientific agriculturist.

7. Planting and seed rate.

This takes place about the middle of March. The seed cane is always buried at the first appearance of frost. Whole canes are buried and not the tops only. In this respect the system of planting in the Gurdaspur District differs from that in Jullundar and Hoshiarpur. In some cases when the season is mild, the seed canes are left standing in the fields. Seed canes which have been buried for some time germinate quicker and better than unburied sets. Discretion has to be used in the time when different types of canes may be buried, as otherwise considerable damage may result. In no other cane country in the world save Louisiana does this system of burying the cane sets exist.

One bundle of canes containing about 500 sticks is the quantity generally used for sowing one *kanal* * of cane (seed rate about $\frac{3}{4}$ ton per acre), and this costs about R. 1. The seed cane is cut into lengths of two eyes each, that is one internode and two nodes. The sets are sown after the plough in lines and are placed nearly a foot from each other in the furrow. The sowers press the sets down with their naked feet as they walk along and about 6 or 7 men are employed in this way for every plough in use. The furrows are set about 8 to 9 inches apart so that the plough does not cover the sets in the preceding furrow—this is done by the *sohaga* which is run 3 or 4 times over the field after the sets have been planted.

8. Cultivation of the crop.

Hoeing. The cane shoots appear above the ground from ten days to a fortnight after planting. A few days before this takes place, the field is hoed with a broad bladed hoe called a *baguri* in which the blade is set at an angle of 45° to the handle. This operation is termed by the farmers " blind hoeing " as it is done before the shoots appear and its object is to improve the texture of the soil so as to render it easy for the shoots to come up in clusters. It also serves to conserve

* One *kanal* = $\frac{1}{8}$ acre

the moisture of the soil. It is said to preserve the sets from attack by termites but in what manner is not clear.

After this hoeing the field is again gone over with the *sohaga* and is then laid out into beds for irrigation. Wherever canal water is available, the irrigation beds are of the roughest type of flooding and no attempt is made to irrigate by furrows. Under well irrigation this is not the case ; for the farmer, having the whole labour and cost of water raising on his hands, takes every care to use his water as economically as possible, and hence a lateral system of furrow irrigation is common on these lands. After a week or so has elapsed, the crop is irrigated for the first time, and when the land comes into condition the field is hoed with a *khurpa*, a small trowel-like implement. After hoeing the soil with this implement, the labourer beats it with his *khurpa* so as to obtain a fine surface ; this serves to retain moisture. One, and if possible two, hoeings are given with the *khurpa* after each irrigation, until the breaking of the rains at the commencement of the monsoon period. In the Gurdaspur District this takes place towards the end of June or the beginning of July.

The crop then receives a hoeing with a large spade, or *kahi* as it is called, and this hoeing is termed " spade hoeing " to distinguish it from that given with the smaller hand implements used in the earlier stages. This latter operation with the spade is the deepest hoeing that crop receives and its object is to let in the rain water and prevent loss of water by surface drainage. All these operations are of particular interest as they show in a marked manner that the Punjab peasant is well aware of the necessity of conserving the natural water supply which the land receives, and that he achieves this in a remarkably efficient manner considering the implements at his disposal. Improvement to be effected will have to be brought about by the more economic use of his power by labour-saving devices and in this respect the spring and peg tooth harrows are becoming popular.

9. Irrigation system in vogue and the quantity of water necessary for the growth of the cane.

The methods of cultivation outlined above indicate in a very clear manner the scarcity of water as compared with the water requirements of this crop in the Gurdaspur District, and applies with equal force to every cane-growing district of the Province. Before the construction of the Bari Doab Canal in 1872-73 there were 62,130 * acres under cane cultivation in the district and of this 8,447 acres of thick cane were under well irrigation and 49,079 acres under *barani* and *sailab* cultivation.

* These figures (the average figures for 1865-69) are the nearest available.

Reference may be made to Table IV, page 7, for the distribution of the cane crop in 1913-14. From this it will be seen that in addition to the area under canal irrigation there is still a great deal of cane grown by means of water raised from wells, and that all the systems of cultivation in vogue 43 years ago are still practised at the present day. As noted in the first pages of this chapter the rainfall of the district varies from 24″ to 50″ per annum, the greater part of which falls during the summer months.

In 1912-13 the rainfall from January to March was 4·3″ (15 per cent. of the whole) and between April and December was 23·82″ (85 per cent.), while in 1916 from January to March it was 5·17″ and from April to June it was 5·47″.

Let us consider for a moment the maximum amount of water which could be conserved in the soil by the various systems of rotation followed.

In the first system above described the land does not possess more than 15 per cent. of the total rainfall of the year at the time of sowing, since the catch crops sown with maize are reaped in the months of January and February. We must not forget that this is the system principally practised.

In the second system the cane follows a cold weather crop after a ten months' fallow. Here we can say that the soil contains upwards of 90 per cent. of the year's rainfall, less that lost by evaporation and transpiration through weeds. In this system it is evident the cane starts with a greater reserve of soil moisture than it does under the first system. Now this latter method is largely practised in the lands irrigated by wells or on the *barani* lands.

In the third system, cane follows cane on *sailab* lands, or is at least only rotated with wheat in the dry years. Hence the land receives an annual flooding and the depth to which this takes place varies considerably. The water table too is much nearer to the surface. For the purpose of our enquiry in this connection we may omit the consideration of this case.

The first is of paramount interest because it is the only method in which we have any records of the amount of water actually applied to the crop. This will be :—

(*a*) Water present in the soil previous to sowing.
(*b*) The amount of irrigation water applied.
(*c*) The rainfall received during the growth of the crop.

Speaking roughly, this will be the annual rainfall plus the irrigation water applied. In the second system the amount of water reaching the crop equals the irrigation water artificially applied plus two years' rainfall less what is dissipated by evaporation. The farmer of course

takes every precaution to prevent water losses under the 10 months' fallow system by continuous ploughing of his land and the establishment of a permanent surface mulch.

Taking the rainfall as from 24″ to 50″ per annum and the amount of irrigation water applied as from 84″ to 90″ (see *Papers Relating to Sugarcane Cultivation in the Punjab*, appendix, page 111, No. 579-Cl, dated March 5th, 1883, from Superintendent of Works, Bari Doab Circle, to the Financial Secretary to Government, Punjab, Public Works Department) we can estimate that the amount of water used for this crop is not less than 108″ and may be as much as 140″.

Under the second system of rotation, the soil may contain moisture equivalent to ten months' rainfall, say, from 20″ to 40″ of water, and receives a further 20″ to 40″ during the growth of the crop, say, in all from 40″ to 80″ of water. In addition to this irrigation, water from wells is applied. We have no accurate measure of the amount of well water applied. All we know is that the irrigation duty of canal water is about one-third of that of well water. From the above figures this could not amount to much more than 30″ of water. This brings up the water requirements of the crop to vary from 70″ to 110″ of water.

Compare this with other cane-growing countries. In Hawaii, Deerr (*Cane Sugar* by N. Deerr, published by Norman Rodger) states this to be 103″ (27″ of rain and 76″ of irrigation), and again on same page (92) to be from 112″ to 123″ inclusive of rain and irrigation water, while O'Shaughnessy[1] places the irrigation duty of water for cane growing in this island as 134″ *not counting natural rainfall.* In Egypt—a country much more comparable with the Punjab—Tiemann [2] gives the irrigation duty of water for cane as 95″ irrespective of rain water and the water present in the soil at the time of sowing. While Leather [3] as a result of pot culture experiments at Pusa places the water requirements of cane as 45·5″ for the season. Summarized these results are as follows :—

Water requirements of the cane crop.

Gurdaspur (a) well-irrigated	70″ to 110″
Gurdaspur (b) canal-irrigated	108″ to 140″
Pusa (Leather)	45·5″
Egypt (Tiemann) upwards of	95″
Hawaii (O'Shaughnessy) upwards of	134″
,, (Deerr)	112″ to 123″
,, ,,	103″
Java (Kammerling's[4] transpiration experiments)	about 18″.

[1] *Transactions of the American Society of Civil Engineers* **54**, 129.

[2] " Sugarcane in Egypt " by Tiemann, published by the *International Sugar Journal.*

[3] *Agricultural Journal of India*, volume VI, July 1911, page 266.

[4] Kammerling. *Proceedings, 4th Congress, United Syndicate of Java Sugar Manufacturers*, 1900.

Two features are remarkable in these figures; firstly, the evident heavy demands of this crop for water, and, secondly, the seemingly close agreement between the amount of water required in Hawaii, where there is a damp island climate, and Gurdaspur which lies over 1,000 miles from the sea and is isolated from it by semi-arid or desert tracts. This latter, however, is not so true as it at first appears.

Deerr (*ibid*) has calculated the amount of water used per lb. of sugar produced. This amounts to 1,000 lb. of water for each lb. of sugar in Hawaii. In Gurdaspur taking a ton of raw sugar per acre as the average out-turn—and this is rather over than under the real figure—we have consumed for every lb. of sugar produced in the case of well-irrigated cane 9,000 lb. of water and in the case of canal-irrigated cane 12,411 lb. of water, or ten times the quantity of water used in Hawaii; in other words, the value of water for cane growing in the Punjab is only one-tenth of the value of water in Hawaii. This result is of the highest importance for it indicates in a remarkable manner the waste of water resulting from the growth of this crop outside its natural zone.

Keatinge [1] gives Rs. 40·11 as the cost of water in Hawaii per ton of sugar. In Gurdaspur the cost is about Rs. 12 for well-irrigated cane, and about Rs. 7 for canal-irrigated cane (per acre). Thus, in spite of the scarcity of water in the Punjab, its value as reckoned by the value of the produce grown is far below the value of water in Hawaii. From every standpoint, therefore, the Punjab farmer when growing cane is obtaining a much poorer return for both land used and water applied than is the case in other sugar-growing countries.

It is our object (1) to obtain such information as will enable us to give an adequate reason for this discrepancy, and (2) to examine the possibilities of removing it. Water is used by the cane crop in two ways; firstly in building up the tissues of the plant itself, of which it constitutes about 95 per cent., and secondly in maintaining an equable temperature of the plant; this is achieved by the transpiration of water through the leaves. Besides this, water is lost by evaporation from the soil, though as we have seen the farmer takes all the precautions known to him to keep this loss down.

Kammerling (*ibid*) has calculated that an acre of cane in Java transpires about 1,800 tons of water in the course of the growing season: this is equal to about 18″ of water.

In a crop of 40 tons of cane, we shall have 38 tons of water. This is equivalent to 0·38″ of water—almost negligible. Lastly we have water losses from the soil. These are evidently very great and constitute

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[1] Paper A 3002, 1914, Bombay

the greater part of the water used. The transpiration losses must vary very considerably, and must be much higher in a dry climate like that of North-West India. In view of the scarcity of water in Northern India further information on this point is urgently required.

From preliminary experiments made at Lyallpur in 1916, it seems that in the application of irrigation water to the land a flooding of 6″ of water does not penetrate more than 8 feet, and that upwards of this quantity is required before a drain gauge $6 \times 6 \times 8$ feet begins to show a discharge. The losses of water from the soil have been calculated as follows :—

TABLE IX.

Farm drain gauge readings. Measurement of the block $=7'\ 4'' \times 6' \times 6'$.

Date of irrigation	Irrigation in inches	Quantity of water passed through in centimeter	Percolation of water in inches	Percolation of water in inches $= \frac{\text{Quantity of water passed through}}{\text{Area of the block}}$
21st February, 1916 . .	2	4951	0·7903	The earth outside the gauge and well was loose and so sank down. Water probably leaked into the receiver.
29th February, 1916 . .	5	6766	0·1080	Do.
13th March, 1916 . .	2·7	61·55	0·009826	Earth sank down but little.
30th March, 1916 . .	2·8	23·18	0·0037	Land seems to have settled down in contact with the plates of the gauge and the leakage observed in the first three cases is not apparent here.
11th April, 1916. . .	3·2	26·61	0·004248	
18th April, 1916. . .	1·9	..	..	
1st May, 1916 . . .	6·2	9·27	0·00148	
3rd June, 1916 . . .	4·0	2007	0·3203	
24th June, 1916. . .	0·59	5·37	0·0008572	Rainfall.
9th July, 1916 . . .	0·84	9·456	0·001510	Do.
13th July, 1916 . . .	0·38	4·576	0·0007310	Do.

TABLE IX—*contd.*

Farm drain gauge readings. Measurement of the block=7′ 4″ × 6′ × 6′ —contd.

Date of irrigation	Irrigation in inches	Quantity of water passed through in centimeter	Percolation of water in inches	Percolation of water in inches = Quantity of water passed through / Area of the block
21st July, 1916 . . .	4·0	..		
22nd July, 1916 . . .	..	16·96		
23rd July, 1916 . . .	..	1372·79		
24th July, 1916 . . .	..	529·16		
25th July, 1916 . . .	..	149·39	0·3378	
26th July, 1916 . . .	..	29·75		
27th July, 1916 . . .	..	9·02		
31st July, 1916 . . .	..	9·33		
		2116		
31st July, 1916 . . .	0·05	..	..	Rainfall
1st August, 1916 . .	..	1·037	0·0001655	
2nd August, 1916 . .	0·17	..	..	Rainfall
3rd August, 1916 . .	..	2·380	0·0003799	
4th August, 1916 . .	0·30	..	..	Rainfall
5th August, 1916 . .	..	1·586	0·0002532	
7th August, 1916 . .	..	1·403	0·000224	
8th August, 1916 . .	..	1·281	0·0002045	
9th August, 1916 . .	..	1·525	0·0002434	
11th August, 1916 . .	2·57	..	..	Rainfall
12th August, 1916 . .	..	584·5	0·09330	
13th August, 1916 . .	1·02	..	..	Rainfall
14th August, 1916 . .	..	2959	0·4723	
15th August, 1916 . .	..	1162	0·1855	

We have no record of what may be the losses of water from the soil elsewhere, but a hot dry climate like that of the Punjab must give very much higher figures than those of an island climate or land near the sea enjoying a moist atmosphere, and this probably accounts for the high water requirements of cane in North-West India. The high temperature will also result in greater losses by transpiration.

10. Harvesting and the length of the season.

Since pig and jackal are not numerous in this tract, with the exception of the Bias and Ravi Bet lands, fencing is not generally resorted to. If it is done, it is usually with the object of preventing trespass. Fields containing sugarcane which are situated near roads are sometimes seen fenced for this purpose, and often the crop is surrounded with a thin line of *sankukra* (*Hibiscus cannabinus*) or *arhar* (*Cajanus indicus*) with this same object.

When the crop is heavy, the stools are tied together in bundles of 2 or 3 shoots by means of their own leaves to prevent laying of the crop.

Cutting and stripping. This is done in the field by manual labour. In some places the labourers are neighbouring farmers who take the cane tops to be used as cattle food in lieu of money payment. 80 men can cut and strip an acre of cane in a day of from 8 to 9 hours.

Harvesting commences in the end of November or beginning of December and goes on until the end of February, and sometimes to the beginning of March.

11. Yields per acre.

As with all agricultural products the yield of the cane is the most important criterion of the condition of the industry, and all attempts at improvement aim first at increasing it. Where a refined product has to be made from the raw material and where, as in the case of sugar making, the material has to be put through a lengthy and complicated manufacturing process, other objects have to be kept in view also, such as the production of a cane which gives a pure juice and one capable of easy refining in the factory.

Important as these objects are, nevertheless they must be considered as second in importance to the out-turn of raw product, for this more than anything else regulates the price of the material at the factory. The yield of cane per acre is difficult to estimate with any degree of accuracy unless the cane from large areas can be weighed. This is never done by the farmers themselves, and they view with suspicion any enquiries of this nature by a Government official, since they imagine the information

will be used for revenue purposes, and will probably result in increased taxation. Their figures therefore are quite useless. We have used three methods for gaining some idea of the yield of cane per acre under the ordinary conditions of country cultivation.

The first is based on a knowledge of the ratio of *gur* to cane, which is roughly 10 per cent. of the weight of cane. This varies according to the efficiency of the mill and the composition of the expression. With ripe cane and good extraction as much as 12 per cent. may be obtained, while with a poor mill and low quality of cane we have seen this ratio as low as 7 per cent.

This estimate is, therefore, only of use in rough field measurements, and in conjunction with a reasonable knowledge of the condition of the crop and of the mill. The other two methods are (*a*) weighing the cane from a small carefully measured area and (*b*) by taking a strip across the crop of a measured area, counting the number of stools and average number of canes per stool in the strip, and from this and a knowledge of the weight of a stool of canes calculating the out-turn per acre. The following two examples will illustrate these methods which were applied in field estimates at Harchowal.

(*a*) Date January 7th, 1913, village Harchowal. A field belonging to Sham Singh, Natha Singh and Naraina.

Type of cane.—*Dhaulu*.

Area of the plot from which the canes were weighed	91×51 feet or 516 square yards approximately.
Weight of cane removed from this plot (after stripping)	39·6 maunds.
Weight of cane per acre	$\frac{4840 \times 39 \cdot 6}{516} = 366$ maunds or 13·46 tons per acre.

(*b*) Area of the strip, the stools of which were counted and weighed.

	$= \frac{35 \times 5}{9}$ square yards.
Number of stools in strip	80
Number of canes in strip	309
Average number of canes per stool	3·88
Weight of canes in the stools	70 seers 140 lb.
Weight of canes per stool	0·881 seer. 1·762 lb.
Number of stools per acre	$\frac{80 \times 4840 \times 9}{35 \times 5} = 19{,}913$
Number of canes per acre	$19{,}913 \times 3 \cdot 88 = 76{,}940$
Weight of canes per acre	$\frac{70 \times 4840 \times 9}{40 \times 35 \times 5} = 435$ maunds = 16 tons approximately.

The following table shows the yields per acre from a number of observations made at Harchowal in January 1913 using both these methods :—

TABLE X.

Date and No.	Owner's name	Area on which the estimate was made	Yield of cane per acre in maunds	
			First method	Second method
1. 7th January, 1913 .	Sham Singh, Natha Singh and Naraina	516 square yards	366	,
" .	"	19·44 yards .	. .	
2. 10th January, 1913	Inder Singh . .	429 " .	308	. .
"	" . .	333 " .	. .	392
3. 10th January, 1913	Mala Singh . .	268 " .	398	. .
"	" . .	225 " .	. .	388
4. 9th January, 1913 .	Rur Singh, Lal Singh	172 " .	544	. .
5. 8th January, 1913	" .	28 " .	. .	477

The estimated out-turn shown in No. 4 in the above table, was from the heaviest cane crop in Harchowal. Many of the stools contained upwards of 20, and a few as many as 25 canes in one stool. Average length of this cane was 6 feet 5½ inches, average length of internodes 3·64 inches, average thickness of the internodes 0·548 inch. The first three estimates were for good average crops near Harchowal, and the average of the first six estimates gives 380 maunds of cane per acre. These results are probably much above the average for the whole district.

In 1882 a general survey of the industry throughout the Province gave the following out-turns. These are not very reliable, since no mention is made of the types of cane on which the estimates were based, and it is well known that thick *Pounda* cane used for chewing and grown under garden conditions near the large cities gives a much higher out-turn than does the country cane grown for *gur* and *shakkar* making.

TABLE XI.

Out-turn of cane (abstracted from Papers Relating to Sugar Cultivation in the Punjab, Punjab Government Press, 1882).

District	Out-turn per acre in tons		
	Cane	Juice	Gur
Karnal	10·7	4·5	0·75
Amritsar	13·2	6·69	0·92
Gurdaspur	7·1	3·2	0·85
Sialkot	6·5	3·25	0·8
Bannu	22·0	..	0·9
Peshawar	17·7	10·8	1·46
Multan	16·0	5·0	1·2
Hoshiarpur	..	..	0·706
"	10·8	5·48	0·94
Jullundar	7·1—17·4	3·3—11·7	0·7—2·2

During the past few years, a record has been kept at the Gurdaspur Experimental Station of the yields obtained there from the ordinary varieties of district cane. These results will be found in Tables XLV to XLVIII, Chapter V, and in the following statement —

TABLE XII.

Yield of cane per acre of the principal varieties in the district (determined at the Gurdaspur Experimental Station).

Variety	Year			
	1913	1914	1915	1916
	M. s.	M. s.	M. s.	M. s
Dhaulu	324 8	379 11	418 6	..
Katha	351 8	260 13	322 7	416 16
Kanara	..	458 10	254 26	359 12
Teru or Tereru	680 5	360 21	428 12	404 32
Kahu	..	270 26	576 21	..
Merthi	366 1	356 27	427 31	..
Kansar	570 3	224 15	441 39	351 8
Bodi	..	544 31	358 4	310 24

The out-turns per acre obtained at the Lyallpur Experimental Station for the principal varieties, *viz.*, Katha, Dhaulu and Kahu were as follows :—

Variety	Year 1911	Year 1912
	Maunds	Maunds
Katha	200	240
Kahu	291	279
Dhaulu	231	..

These canes received 15 tons farmyard manure per acre.

On the whole I am inclined to believe that 10 tons of stripped cane to the acre is probably a very fair average for *Katha* for the whole of the Gurdaspur District, and perhaps a little higher than this for *Dhaulu.* The other types grown are too variable and too liable to the influence of climatic changes to admit of any round figures being given for their out-turns.

At the same time the very wide variation in the yield obtained for cane in the district shows that improvement can be effected in this direction. In Tables XLV to XLVIII in Chapter V are given the results of a number of variety trials at Gurdaspur in 1913-16.

In 1913-14 *Bodi* gave the highest yields of cane, and *Desi Suretha* the highest yield of *gur,* being 19·9 and 1·3 tons respectively ; while in 1914-15 *Mango* gave the highest yield of cane and *Reora* of Benares the highest yield of *gur,* being 23·9 and 1·9 tons. These high out-turns are not entirely due to the variety alone, for we find that local canes like *Dhaulu* and *Katha,* when grown on the Government Farm at Gurdaspur, gave 17½ tons and 11·9 tons of stripped cane to the acre. These figures are probably much higher than those usually obtained by zemindars. The average yield of *gur* from the Gurdaspur Farm figures for local canes is 10·5 per cent. of the weight of the cane, and from the Lyallpur Farm 10·3 per cent. of the weight of cane. We can safely assume that the cane per acre will not be less than ten times the weight of *gur* made from it in this district, since the method of manufacture is uniform, the same type of mill and boiling plant being used throughout.

On a five-acre experiment of well-irrigated *Dhaulu* cane at the Gurdaspur Experimental Farm the crop was good and probably above the district average. The yield of *gur* was from 25 to 30 maunds per acre. This may be taken as a fair average figure for the district.

Taking the whole district the yield does not average more than 25 to 27 maunds of *gur* to the acre. On the above basis of calculation, namely, that the weight of cane is approximately ten times the weight of *gur* made from it by the process of manufacture used there, this would give a yield of 9·2 to 11 tons of stripped cane per acre. Ten tons of cane per acre may consequently be taken as a fair average.

A close study of this factor of yield reveals a wide seasonal variation even on the same soil, and manurial experiments have so far failed to yield conclusive results. We are forced to the conclusion here, as in other experiments, that season is one of the most important and influential factors in regulating the growth and out-turn of sugarcane in the Gurdaspur District.

12. Diseases and pests.

Little or nothing is known about cane diseases in this district. Red rot (*Colletotrichum falcatum*) is prevalent, and occasionally causes the complete destruction of entire fields of the softer canes of recent importation like *Kahu*.

Butler in 1914 found *Fomes Lucidus* (Leys.) on Gurdaspur cane stems, but this was identified in connection with the ivory markings on *Dhaulu* and was not suspected of causing any loss in the crop.

The cane suffers from a number of unstudied insect pests, which cause considerable damage and loss in wet seasons and on cane grown under canal irrigation, both perennial and inundative.

Subject as the district is to cold and damp, the losses caused from diseases must be great.

CHAPTER II.

MANUFACTURE : WORKING UP THE RAW PRODUCT.

1. Extraction of the juice.

The canes are cut immediately before crushing in order to avoid deterioration in the quality of the juice. The old wooden mill or *belna* has almost disappeared from Gurdaspur, though it can still be seen in parts of Jullundar and Hoshiarpur. In the Gurdaspur District iron mills of the two roller type are most commonly used, though during the last few years three roller mills have been coming into use. Better types of mills are made in Batala and cost respectively for 2 and 3 rollers Rs. 28 and Rs. 35 per mill. If worked through an entire season, they last for four or five years. Superior three roller Nahan mills are occasionally seen, but these are usually hired at the rate of Rs. 78 per season. The cheap Batala mills are nearly always bought outright. The extraction effected by these mills is poor, and there is much room for improvement in this direction.

With the best type of three roller mill the extraction is generally under 60 per cent. of juice or less than 80 per cent. effective extraction of the sucrose. The two roller Batala mill is much less than this. I shall refer to this point later in describing Hulme's experiments in the United Provinces.

The two roller Batala mill will express about 96 lb. of juice per hour, while the three roller Nahan mill on the Gurdaspur Farm expresses 140 lb. of juice from *Katha* cane and 180 lb. from *Kahu* cane per hour.

With the old wooden mill, in which the cane was passed through the rollers from ten to fifteen times, the extraction was about 50·7 per cent. as will be seen from the following table :—

TABLE XIII.

Extraction effected by the old wooden mill.[1]

	Percentage of juice extracted
Karnal	42
Gurdaspur	50
Sialkot	50
Hoshiarpur	50
Jullundar	67*
	50
	58
	46
	50
	69*

[1] Papers relating to Sugar Cultivation in the Punjab. (*loc. cit.*)

* These high extractions were probably from thick canes of the *Pounda* type—the report makes no mention of the variety used in these tests.

Lehman [1] states that from 20 to 33 per cent. of the juice is left unextracted by the wooden mill (this represents a loss of 20 per cent. of sugar).

Clarke and Annett [2] give the following as the efficiency of the Nahan three roller mill.

Average of juice extracted.

	1908-09	1909-10	1910-11.
Average extraction .	59·7 per cent.	62·5 per cent.	63·1 per cent.

The following table shows the extraction effected by this type of mill with the Gurdaspur canes in 1912.

TABLE XIV.

Table showing the extraction effected by the three roller Nahan mill at Gurdaspur.

Number and date of the sample	Description and locality of the cane	Grams of juice extracted from 100 grams of cane	Percentage of fibre in the cane	Percentage of the total sucrose present in the cane extracted in the juice = Efficiency of mill in sucrose extraction
	Tereru—			
16, 2nd January, 1912 .	Government Farm, Gurdaspur	63·2	15·36	76.3
25, 4th „ „ .	No. 5 Government Farm, Gurdaspur	57·9	20·10	77·2
	Dhaulu—			
31, 5th January, 1912 .	Ghurala, Gurdaspur	58·7	21·21	83·4
46, 8th „ „ .	Hailehalan, Gurdaspur	61·1	15·95	83·5
50, 10th „ „ .	Ghuman, Gurdaspur	59·4	22·13	86·0
58, 11th „ „ .	Chuhar chak, Gurdaspur	52·5	27·48	80·0
195, 1st February, 1912.	Ahmadabad, Batala	55·3	17·78	79·0
220, 5th „ „ .	Chowra, Batala .	57·8	18·23	81·3
257, 13th „ „ .	Ahmadabad, Batala	51·6	21·82	75·6
	AVERAGE FOR DHAULU	56·6	20·60	81·2

[1] *Agricultural Journal of India*, vol. II, page 57.

[2] Clarke and Annett. Experiments on the cultivation of sugarcane at Partabgarh Experiment Station, 1909-11. *Pusa Agri. Res. Inst. Bulletin*, no. 27, page 8.

TABLE XIV—*contd.*

Table showing the extraction effected by the three roller Nahan mill at Gurdaspur.

Number and date of the sample	Description and locality of the cane	Grams of juice extracted from 100 grams of cane	Percentage of fibre in the cane	Percentage of the total sucrose present in the cane extracted in the juice= Efficiency of mill in sucrose extraction
	Katha—			
66, 12th January, 1912 .	Bhumli, Gurdaspur	52·9	23·63	79·04
98, 16th " " .	Haweli, Gurdaspur	52·9	27·76	85·04
106, 17th " " .	Joura Chhitran, Gurdaspur	59·4	19·89	85·0
115, 18th " " .	Gurdasnangal, Gurdaspur	60·3	18·42	83·7
116, 19th " " .	Kalanaur, Gurdaspur	60·5	19·77	83·9
28, 21st " " .	Shahpur Guria, Batala	59·0	18·57	81·5
142, 23rd " " .	Gurman, Batala .	47·4	29·53	76·6
152, 25th " " .	Barila Kalan, Gurdaspur	69·9	11·97	83·0
157, 26th " " .	Mela-Athwal, Batala	54·2	24·93	78·4
187, 31st " " .	Wanjwan, Batala .	55·8	22·72	82·4
234, 7th February, 1912.	Kotla Musa, Batala	52·6	26·30	71·2
241, 9th " " .	Sandalpur, Gurdaspur	58·4	20·07	75·4
247, 10th " " .	Morarah, Gurdaspur	57·2	22·90	74·7
260, 14th " " .	Dadiala, Gurdaspur	56·6	23·91	77·1
	AVERAGE FOR KATHA .	56·7	23·57	79·8
	Katha and Dhaulu mixed—			
89, 14th January, 1912 .	Walta Gumunpur, Gurdaspur	60·0	18·20	80·0
90, 18th " " .	Baheholi, Gurdaspur	47·3	28·25	72·3

TABLE XIV—*concld.*

Table showing the extraction effected by the three roller Nahan mill at Gurdaspur.

Number and date of the sample	Description and locality of the cane	Grams of juice extracted from 100 grams of cane	Percentage of fibre in the cane	Percentage of the total sucrose present in the cane extracted in the jutice= Efficiency of mill in sucrose extraction
	Kansar—			
19, 3rd January, 1912 .	Government Farm, Gurdaspur	67·5	15·28	84·2
120, 20th " " .	Padhal, Gurdaspur .	62·3	15·83	86·6
134, 22nd " " .	Kahlianwali, Batala	61·7	16·76	87·4
165, 27th " " .	Kotli Tahlan, Batala	53·6	25·44	78·5
	AVERAGE FOR KANSAR	61·5	18·33	84·1
	Teru—			
38, 7th January, 1912 .	Dhariwal, Gurdaspur .	55·9	22·47	75·6
32, 6th " " .	*Katha and Teru* .	59·8	17·97	79·3
74, 13th " " .	Do., Thikriwala, Gurdaspur	58·3	17·72	80·2
	Kahu—			
203, 2nd February, 1912.	Dialgahr, Batala .	63·0	13·73	77·6
217, 4th " " .	Sarupwali, Batala .	66·8	14·29	83·4
228, 6th " " .	Mari Pannan, Batala	66·3	12·60	80·6
	AVERAGE FOR KAHU .	65·4	13·54	80·5
	Katha Kahu—			
148, 24th January, 1912 .	Jourian Kalan, Batala	53·2	17·15	79·3
179, 29th " " .	Dabhanwali, Batala	87·1	21·60	81·0
	Pounda—			
211, 3rd February, 1912 .	Kaka, Batala .	65·3	10·60	78·0

The juice extraction varies from 56 to 67 per cent., and the efficiency of the mill in sucrose extraction varies from 71 to 87 per cent., with an average of under 80 per cent. for the common canes of the district. *This represents a loss of upwards of 20 per cent. of sugar, and under what we may consider the best methods of extraction now at the disposal of the farmer.* The farmers mostly use the two roller Batala mill, in which the extraction is much less and the losses correspondingly greater. (See Hulme's estimate for the United Provinces, Chapter V.) This indicates very clearly the need for heavier mills and better extraction. Geerligs [1] states that the sucrose extraction in Java is about 91 per cent. of the sugar in the cane, with a loss of about 1·1 per cent. of sucrose in the bagasse on canes containing about 11 to 12 per cent. of fibre. All the district canes contain much more fibre than this, as may be seen from the tables in Chapter III. One of the objects in cane improvement will be to obtain a less woody cane. With this object I imported several varieties of cane from Egypt in 1912. One of these is Java seedling No. 105 which has been introduced into Egypt from Java by Monsr. Nous, managing director of the Egyptian Sucories Cie. This cane was doing well there when I visited Egypt in 1912. I anticipated that a cane which was suited to the dry climate of Egypt would probably do well in the Punjab. The analysis of this cane is as follows :—

Locality and date of analysis	Juice per cent. on cane	Glucose	Sucrose	Total solids	Glucose ratio	Purity co-efficient	Fibre on cane
		(per cent in juice).					
Government Farm, Lyallpur, 5th January, 1915	63·01	0·32	11·61	15·40	2·84	76·03	13·90
Government Farm, Gurdaspur, 21st January, 1916	70·21	2·57	8·75	13·06	29·32	67·05	9·24

It is interesting to note that with the mill at my disposal I was unable to trace any numerical relationship between the extraction value and the amount of fibre in the cane. There was a fairly close agreement between different extractions of the same variety of cane even when the amount of fibre differed considerably.

2. Boiling the juice.

The mill is always situated near to the boiling pans so that the juice can be taken straight from thence to the pans, and for this purpose the empty kerosene oil tin so much in evidence in North India is almost

[1] Geerligs' *Cane Sugar and its Manufacture.*

always used nowadays, though the old earthen jar is still to be seen in the more remote villages.

The boiling house is a mud hut roofed with beams and brushwood and overlaid with earth in the usual manner of the Punjab peasant's dwelling. The pit of the furnace is in the floor of the room and has an exit for the ashes outside, there being a slanting hole from the furnace to the ash pit. The fire is directly under the pans. The pans in use in this district are all of one pattern and are of iron being constructed by the local village blacksmiths. They cost about Rs. 17 each, and are from 4½ to 5 feet in diameter and a foot deep at the centre. They hold about 120 lb. (12 gallons) of juice per boiling.

The two roller Batala mill expresses about this quantity of juice in 1¼ hours, and the boiling of this amount occupies about the same time. The three roller Nahan mill on the Gurdaspur farm expresses 140 lb. of juice from *Katha* cane and 180 lb. of juice from *Kahu* cane per hour. The bagasse is dried in the sun and used as fuel. As a rule it serves to evaporate the juice to the consistency of *gur*, except in the case of the more juicy canes when this source of fuel has to be augmented by cotton stalks or other local fuels.

Gur-making is a continuous process and is carried on night and day during the season. It only ceases with the cessation of cane cutting by rain, or when the bullocks have to be taken from the mill to work on the wells for irrigating wheat. The boiling begins about 9 months after sowing time towards the end of November or beginning of December. The juice after crushing goes straight to the pan without straining, except in special cases when the product is for private consumption or when making *rab*.* The juice is boiled until the scum rises ; this is then removed with ladles. It is unusual in *gur*-boiling to induce the formation of scum by the addition of foreign substances. In some cases the sugar boiler adds a little common soda. This improves the colour of the *gur* but impairs its keeping properties.

In the manufacture of *mal rab* (a liquid raw sugar) *suklai* or *suli* (*Euphorbia Royleana*) is added.†

After the removal of the scum and when the juice begins to boil, a little sweet oil (sesame oil) is added to check violent ebullition, and at the same time the fuel in the furnace is reduced. When the charge begins to assume a semi-solid consistency, vigorous stirring is resorted to.

* *Rab* is a raw sugar product—for its composition see page 38.

† This bark when steeped in water gives a thick soupy solution of pentosans which precipitates on boiling, thus aiding the clarification of the juice. It serves the same purpose as white of egg in clarifying soup or bouillon in the preparation of bacterial culture media, or of fresh blood in the old West Indian sugar-boiling process.

The product is then transferred to a flat earthen vessel called a "gand," where it is kneaded into balls of about 2 lb. in weight.

From superior ripe cane a whiter product termed "shakkar" is obtained which is dryer and more friable; this is usually sold in the powder form. When boiling for *shakkar*, the charge of juice is slightly reduced and the concentration carried a little further than when making *gur*.

Mal rab. The process of *rab*-making differs from that of *gur*-making in the clarification of the juice and in the concentration not being carried so far. The contents of the pan are removed into large earthen jars and stored in a semi-solid, semi-liquid state until required for *khand*-making.

The proportion of juice to *rab* is about 5 to 1 and of juice to *gur* about 6 to 1.

Manufacture of khand—*a drained raw sugar.*

This process has been described by Montgomery in the Hoshiarpur settlement as follows :—

"The making of drained raw sugar, "khand," is generally carried out by a regular trader. The process requires a good deal of superintendence and few cultivators proceed further than the making of the first crude sugar products, *gur* and *mal rab.* In making *khand* the *mal rab* is emptied into large vats called "khanchi," which are made of wood and lined with matting. They are capable of holding from 80 to 400 maunds of *rab.* At the bottom of the vats are a number of small channels leading off to special reservoirs outside, and on this flooring are placed pieces of wood on which is a reed mat and over that a piece of coarse cloth the sides of which are sewn to the side mats in the vat. After a time the molasses known as *shira* exude through the cloth and matting at the bottom to the reservoirs and are thence collected in earthen jars. After the *rab* has been in the vat about 10 days, and the mass has hardened sufficiently to bear a man's weight, it is worked up with an iron trowel so as to break up all lumps, and then smoothed with a flat dish previously rubbed with *ghi.** The layers of *jala* (*Potamogeton*), a water plant, are placed on the top, and after every few days the *jala* is rolled up and the white sugar at the top of the mass of *rab* is taken off and fresh *jala* put in its place, the old *jala* being placed over, so that as the sugar is extracted the super-incumbent weight of *jala* increases. Towards the end it is found that the weight of *jala* is carrying sugar as well as molasses through the cloth strainer. It takes 3 or 4 months to empty a vat in this way. If begun when the weather is cold,

* Clarified butter fat.

it is customary to light fires in the room containing the vats before putting on the *jala*, in order to make the molasses draw off quicker. The sugar taken off is spread out on a piece of coarse canvas on a hard piece of ground in the sun and is well trodden with the feet until it has been reduced to a coarse powder. This substance is called *khand*, and sometimes *chini*, and is the ordinary coarse ground sugar sold in the bazaars."

Sri Gobindpur is the centre of the *khand* industry in the Gurdaspur District, but *khand* is still made in several villages in the neighbourhood of Harchowal.

The following figures were obtained from the village of Jagalwala near Harchowal. Dimensions of the vat $7 \times 4\frac{1}{2} \times 4\frac{1}{2}$ feet. Capacity 120 maunds (4·4 tons). The *rab* contained in it had been prepared from a *barani* crop of mixed *Katha* and *Dhaulu* canes. The following estimate of expenditure and receipts was given by the owner :—

Expenditure.	R	a.	p
Cost of *rab* at Rs. 3-15-9 per maund	478	2	0
Wages of workmen for $2\frac{1}{2}$ months at Rs. 10 per month	25	0	0
Sweet oil for cleaning the juice and for burning at the rate of $\frac{1}{3}$ seer per day for 60 days costing R. 0-8-6 per seer	10	0	0
Cost of *sukhi*	1	0	0
Cloth for bottom of vat	1	8	0
Cost of earthen vessels	0	8	0
Cost of *jala* at 4 annas per layer	5	0	0
Cost of treading out the sugar at 8 annas per day (rate 5 maunds per day)	3	0	0
Interest on Rs. 500 at 5 per cent. for 12 months . .	25	0	0
TOTAL EXPENDITURE .	549	2	0
Receipts.			
30 maunds *khand* at Rs. 12-8-0 per maund	375	0	0
70 maunds molasses at Rs. 2-10-6 per maund . .	185	15	0
TOTAL RECEIPTS .	560	15	0

Nowadays the return on the industry is from 8 to 10 per cent. of the money invested, while in former years it was 15 per cent. The falling off is attributed by the *khand*-makers to the decline in the quality of the *rab*, which they say is due to the abandoning of the long fallow system of

cultivation. The *rab* industry is certainly on the decline but it is impossible to say if this is due to the poorer quality of the cane, since there is no record of the chemical composition of cane juice in previous years.

In all probability, several factors have contributed to the decline of this industry, and not the least among them is the rise in the price of raw sugar commodities with the extension of trade, which brings other agricultural products into more direct competition with local cane (*see* Chapter V, crops in competition with cane). The importation of refined sugar from abroad has also had its influence on this local industry (*see* Chapter IV). In the village of Jagalwal from 10,000 to 12,000 maunds of *rab* were made annually, and its manufacture has declined until at the present day only 350 maunds of *rab* are used for *khand*-making.

3. Sugar products and their composition.

The principal sugar products made in the district are as follows :—

(*a*) *Gur*—a raw sugar made by simple evaporation of the juice (see above).

(*b*) *Shakkar*—a light dry *gur*.

(*c*) *Rab* or *mal rab*—liquid sugar (see above).

(*d*) *Khand* (see above)—a refined sugar from which molasses have been drawn off.

(*e*) *Bura*—made from *khand* boiled in water and clarified with milk.

(*f*) *Misri*—prepared from *khand* boiled with water and evaporated.

(*g*) *Kuza misri*—prepared as *misri* only with the best type of *khand*.

In the preparation of *kuza misri* the best quality of *khand* is dissolved in boiling water to the consistency of a thick syrup. This is placed in small porous earthen vessels in which is suspended a cotton thread. When the sugar has crystallized the vessels are inverted to draw off the mother liquor, they are afterwards broken in order to secure the crystallized sugar in a lump. This is the ordinary candied sugar.

(*h*) Sugar raw—By this is meant "sugar un-refined," under which *bhura* or *bura sakar* or brown *shukkar*, *karkar* or *masti meeja* or *talauncha* and other local names are classified. The term does not include *gur* and molasses.

The composition of these materials may be judged from the accompanying table :—

TABLE XV.

The composition of various sugar products produced in the Gurdaspur District in 1914 and 1916.

Register No. for reference	Date of analysis	Description of the product under examination	Glucose per cent.	Sucrose per cent.	Specific gravity of solution	Total solids Brix. corresponding to sp. gravity	Total soluble matter	Moisture and insoluble impurities	Soluble organic impurities	Total solids as cane sugar by refractometer	REMARKS
149	30th July, 1914 31st July, 1914	*Bura* made in Qadian	6·45	81·04	1·0354	8·86	88·6	11·4	1·11	88·75	
150	Do.	*Misri* made in Sri Gobindpur from country *khand* made from cane grown in the Bet	2·12	90·61	1·0375	9·36	93·6	6·4	0·87	92·5	
151	Do.	*Khand* from Sri Gobindpur made from *Dhaulu* and *Katha* grown in Beas Bet	1·30	91·81	1·038	9·49	94·9	5·1	1·79	93·75	
152	Do.	*Khand* prepared in Qadian	1·05	93·26	1·0382	9·53	95·3	4·7	0·99	93·0	
153	Do.	*Khand* prepared in Harchowal from *Katha* cane	1·80	92·21	1·0378	9·44	94·4	5·6	0·39	92·5	
179	Do.	*Shakkar* from *Dhaulu* cane at Harchowal	9·29	75·6	1·0370	8·965	89·65	10·35	4·76	..	
168	Do.	*Gur* from *Dhaulu* at Gurdaspur	13·34	73·21	1·0363	8·805	88·05	11·95	1·5	..	*Gur* is very variable in composition
102	31st July, 1916	*Rab (Shira)*	29·68	41·02	1·0330	8·27	82·74	17·26	12·04	81·50	
101	Do.	*Kuza misri*	0·13	96·90	1·0389	9·70	97·0	3·0	nil	97·00	

4. Yield of *gur* and sugar in the *gur*.

The out-turn of *gur* obtained in this district varies with the type of cane from which it is made, with the cultivation this receives, and with the season. The milling which the cane gets is fairly uniform throughout the district, and we cannot say with any certainty that there is much variation on this account.

The following table gives the yield of *gur* (raw sugar) per acre of the principal varieties of cane grown in the district (determined at the Gurdaspur Experimental Station) :—

TABLE XVI.

Table showing the yield of gur *per acre at Gurdaspur.*

Variety	1913	1914	1915	1916
	M s.	M. s.	M. s.	M. s.
Dhaulu	26 0	30 6	32 25	..
Katha	38 2	23 20	30 10	29 20
Kanara	..	38 23	26 36	24 18
Teru or Tereru . . .	52 32	31 10	36 12	26 33
Kahu	..	24 9	46 10	..
Merthi	42 14	26 12	25 4	..
Kansar	53 35	24 22	42 10	19 18
Bodi	..	40 7	32 32	21 24

These figures are the result of a number of crushing and boiling experiments made on the Gurdaspur Experimental Farm, and are from canes grown there. The weight of cane crushed may be seen by reference to Table XII (Chapter 1, page 26).

More reliance may be placed on the results shown for 1914, 1915 and 1916 than for 1913, when only small areas of cane were grown. In considering the results of this table, it is important to note that these have been obtained from the use of a three roller Nahan mill which gives a higher efficiency than that obtained by the zemindar in the district, who for the most part uses the two roller Batala mill.

From a knowledge of the chemical composition of the *gur* and the amount obtained per acre, we can estimate the actual amount of the biose sugar sucrose produced and recovered in the *gur*. If we allow for the efficiency of the mill as shown above to be about 80 per cent., the actual sugar produced per acre and recoverable as *gur* can be ascertained with a fair degree of accuracy. These figures are of interest to the manufacturer of refined sugar when working on *gur* as the raw product ; they will not be accurate for the actual sucrose production, as this must be calculated on the analysis of the cane itself.

TABLE XVII.

Composition of raw sugar (gur) *prepared from district canes grown and crushed at the Gurdaspur Agricultural Station.*

Variety and year		Glucose per cent.	Sucrose per cent.	Specific Gr. of 20 per cent. solution	Total solids Brix	Percentage of soluble matter	Percentage of moisture and insoluble impurity	Soluble organic impurity	FROM GUR	
									Sucrose per acre from table (in pounds)	Estimated out-turn of sucrose per acre allowing for mill losses as 20 per cent. (in pounds)
Katha	1913	15·37	72·29	1·0732	17·8	89·0	11·0	1·34	2,310	3,081
	1914	8·74	72·36	1·0740	17·9	89·5	10·5	8·40	1,412	1,765
	1915	9·11	70·41	1·0720	18·0	90·0	10·0	10·48	1,753	2,191
Kansar	1913	14·68	72·31	1·0730	17·8	89·0	11·0	2·01	3,244	4,386
	1914	9·75	71·81	1·0746	18·05	90·25	9·75	8·69	1,874	2,342
	1915	8·92	64·54	1·0756	18·9	94·5	5·5	21·04	2,229	2,786
Merthi	1913	12·32	74·95	1·0733	17·8	89·0	11·0	1·73	2,654	3,317
	1914	15·26	69·72	1·0722	17·5	87·5	12·5	2·52	1,531	1,913
	1915	11·07	71·10	1·0756	18·9	94·5	5·5	12·39	2,455	3,069
Tereru of Batala	1913	17·39	68·15	1·0713	17·3	86·5	13·5	0·96	3,020	4,640
	1914	12·79	72·83	1·0733	17·75	88·75	11·25	3·13	1,903	2,379
	1915	15·24	66·41	1·0757	18·30	91·50	8·50	9·85	1,976	2,470
Dhaulu	1915	18·36	62·57	1·0766	18·45	92·25	7·75	11·32	1,675	2,094
	1916	21·75	59·33	1·0756	18·26	91·31	8·69	10·23	..	..

NOTE—Milling losses in the district are greater than this.

5. Losses of sugar in the manufacturing processes.

The losses which take place in working up the cane into marketable forms of sugar are also considerable. This is only to be expected when we consider the crude machinery at the disposal of the farmer and his lack of knowledge of the chemical processes involved in sugar boiling.

The first loss is in the milling of the cane. We have already described this in discussing the efficiency of the mills in use, and have estimated that upwards of 20 per cent. of the available sugar is lost in this process alone. The next great waste occurs in the boiling of the juice. Since the juice is always boiled immediately after crushing the cane, and as crushing goes on simultaneously with the harvesting of the crop, there are practically no losses in the cane itself before crushing.

In the boiling of the juice, however, a great deal of sugar is lost. Some sugar is lost by inversion, and this is inevitable since the juice is acid, and the attempts made to neutralize the acid are extremely crude and sometimes are absent altogether. Mention has been made above that sometimes a little crude soda is added to the juice in *gur* boiling, but this is not often practised, since the use of soda often leads to the production of an inferior raw sugar. This is because the soda can never be added in the exact proportion necessary to neutralize the acids present without the use of test papers, and such are unknown to the zemindar. The use of lime in sugar boiling is quite unknown in this district.

The following table has been compiled from Tables XII, XIV, XVI, and XVII, and shows the amount of sugar per acre in the cane and the amount of sugar recovered in the *gur* :—

TABLE XVIII.

Losses in the manufacture of raw sugar (gur) *at the Gurdaspur Experimental Station.*

Variety of cane and year of experiment		Sucrose per cent. on cane	Sucrose per acre in pounds	Invert sugar per cent. on cane	Invert sugar per acre in pounds	Pounds of sucrose in the *gur* from one acre of cane	Pounds of invert sugar in *gur* from one acre of cane	Total loss of sucrose per cent.	Sugar lost by inversion per cent.	Sugar lost in milling per cent.	Other losses, at present unaccounted for, per cent.
Dhaulu	1914	10·38	3,216	0·36	102	1,880	189	41·55	3·96	20·0	17·59
	1915	10·36	3,550	0·29	100	1,674	491	52·84	13·74	20·0	19·10
Katha	1913	12·14	3,495	0·45	130	2,255	479	35·47	13·68	21·0	0·79
	1914	10·55	2,252	0·61	128	1,395	169	38·0	3·83	22·83	11·34
	1915	11·07	2,923	0·31	82	1,747	226	40·2	6·64	21·0	12·56
Teru	1913	12·36	6,905	0·20	112	2,950	754	57·3	11·90	23·0	22·40
	1914	11·25	3,326	0·45	133	1,866	328	43·9	8·37	23·0	12·53
Kahu	1914	10·34	2,295	0·20	44	1,336	248	46·1	10·9	19·5	15·70
Kansar	1913	10·89	5,091	0·53	248	3,194	649	37·3	9·8	16·0	11·5
	1914	11·57	2,177	0·89	163	1,445	196	33·6	3·1	16·0	14·5

These figures have been arrived at from a knowledge of the mill expression, the weight of cane and *gur* obtained per acre of crop grown and the analyses of the juice, bagasse and *gur*. I have not considered it necessary to give the details of the calculations as these are comparatively simple. The quantity of sucrose lost by inversion is obtained from the gain in invert sugar on boiling; this figure multiplied by the factor $\frac{324}{360}$ gives the equivalent amount of sucrose, and is taken to represent that lost by inversion. The gain in invert sugar is obtained thus :—

We know that, unless the mill expression is very high, the glucose ratio $\frac{\text{glucose} \times 100}{\text{sucrose}}$ is approximately the same in juice and bagasse. Any mill losses therefore will have to be taken into account. If, as in the case of *Dhaulu* cane in the above table, our milling losses on sucrose weie 20 per cent., then an equal loss would occur in the glucose and the 100 lb. of glucose from 1 acre of cane would in the course of its milling fall to 100—($\frac{100 \times 20}{100}$). This figure of 80 lb. of invert sugar should be present in the *gur* if only milling losses occur and no change takes place in the composition of the juice. By analysis, however, we find that the *gur* contains 491 lb. of invert sugar, so it has gained 491-80 lb. and this is from sucrose which has become inverted. This is equal to (491-80) $\times \frac{342}{360}$ equal to 390 lb. sucrose lost by inversion, equal to 13·7 per cent. on the sucrose in the juice of the cane.

From the above table the total loss of sucrose in *gur* making appears to vary from 34 to 57 per cent. *or nearly one half of the sucrose in the cane is lost in this process of raw sugar making.*

Of this whole loss, from 16 to 23 per cent. is due to bad milling and from 3 to 14 per cent. to inversion of sucrose in boiling the juice From 1 to 22 per cent. of the loss remains unaccounted for. It is probably due to losses in handling the raw and manufactured products, petty theft, in destruction of sugar in boiling and in a lower milling efficiency than that recorded. The extent and nature of this loss requires further investigation. I do not presume to state that in all *gur* making processes and with all canes, the losses are as high as 50 per cent. : they may in some cases be less, but this is unlikely since the mill used in these experiments (Nahan) was of a better type than is usual with the zemindar.

Clarke [1] gives an expression of from 71 to 87 per cent. for various canes, using this same type of mill, and our results at Gurdaspur fall within the limits quoted by the above observer. We know that the expression effected varies with the rate at which the mills are made to

[1] *Pusa Bulletin* No. 42 : Notes on Cane Crushing in the United Provinces, pages 7 and 8.

revolve as well as with their adjustment. It also varies with the nature of the cane. The figures in the above table are, therefore, to be taken as approximately representative only. They are sufficiently accurate, however, to give us some idea of the magnitude of the losses effected in making raw sugar under the best possible prevailing conditions, and they indicate the immediate need of improvement, if cane cultivation is to compete successfully with the other agricultural products grown in the district.

CHAPTER III.

THE CHEMICAL COMPOSITION OF THE DIFFERENT VARIETIES OF CANES GROWN IN THE DISTRICT.

1. System followed for sampling the canes and recording the results.

The usual methods of cane analysis were followed in obtaining the figures referred to in this report.

In sampling a field crop like cane, considerable errors are liable to be made owing to variations in the field. These may be so variable that the different canes of one soil may show a considerable variation in the composition of the expression. The only really satisfactory method is to examine the juice and bagasse several times in the course of the passage of a large quantity of cane through a standard mill so set and controlled as to give a fairly uniform extraction. In such an enquiry as the one described here, this was of course impossible. It was easier to multiply the number of analyses and strike an average than to undertake the costly arrangements attendant on the experimental crushing of large measured areas of cane. Another point in favour of the system adopted was that the ripening of the cane could be followed simultaneously in different parts of the district by carrying out the analysis at a central laboratory. A small laboratory was set up in the office attached to the Government Experimental Station at Gurdaspur, and the cane samples were collected in selected villages in the adjacent country and at such distances that not more than 24 hours elapsed between the cutting of the sample and its analysis in the laboratory.

One or two stools of cane were selected for each sample by the Field Assistant deputed for the work, care being taken to select an average rather than a good stool, and always at some distance from the edge of a plot of growing canes. The cane after cutting was stripped of leaves and then wrapped in the cane leaf, and at once despatched by messenger to the laboratory. As far as possible the sampling was done in the afternoon or evening so that the material reached the laboratory early the following morning or at least by mid-day. The cane was then weighed and milled in a three roller Nahan mill driven by bullocks, a record being kept of the amount of juice expressed.

Under these conditions, there is a probability of change taking place both in the concentration of the juice and in its composition. The

stripping of the stem and the wrapping in the cool and moist cane leaf reduces the change in concentration to a minimum. Even in exposed cut cane in bulk the loss in weight does not usually amount to more than 2 per cent. according to Deerr (*loc. cit*). Weinberg estimates the loss of available sugar during the first 24 hours as about 2·7 per cent. It is not an uncommon practice among farmers in the Gurdaspur District to allow a day to elapse between cutting and crushing and this practice is said to yield a dryer and better *gur*.

The loss of sugar resulting from storing canes was examined at the outset of these experiments and the results obtained are given below in Table XIX.

In the above experiment the cane samples were stripped of leaves and analysed after storing for 24 to 48 hours. Out of 20 samples, only 4 showed a decrease of sucrose.

TABLE XIX.

Showing the change in composition of sugars in juice on storing canes.

Special experiments on the effect of stripping the cane on the suciose contents.

Chak No. 79 near Agricultural Station, Lyallpur.

Special analysis of red, thin *Chin* purchased from Rura tenant.

No. and date of sample	Description and locality of cane	Juice per cent.	Glucose per cent.	Sucrose per cent.	Total solids	Glucose ratio	Purity co-efficient	Fibre on cane	Increase or decrease on the sucrose
1. 6th March 1912	Red thin *Chin*. Rura tenant, Chak 79, near Agricultural Station, Lyallpur	50·4	0·21	19·13	23·1	1·09	82·79	23·96	..
2. 7th ,, ,,	No. 1 after 24 hours	49·6	0·37	19·58	23·1	1·89	84·78	24·14	+0·45
3. 6th ,, ,,	Another stool analysed fresh	52·19	0·17	17·60	22·5	0·96	78·21	22·68	..
4. 7th ,, ,,	No. 3 after 24 hours	50·7	0·78	18·08	23·2	4·31	77·91	22·43	+0·48
5. 6th ,, ,,	Another stool analysed fresh	48·7	0·12	17·72	22·2	0·68	79·82	19·13	..
6. 7th ,, ,,	No. 5 after 24 hours	50·2	0·46	18·45	23·0	2·49	80·23	21·79	+0·73
7. 6th ,, ,,	Another stool analysed fresh	50·08	0·23	17·60	22·5	1·30	78·2	22·61	..
8. 8th ,, ,,	No. 7 after 48 hours	52·07	0·34	18·86	24·2	1·80	77·93	22·10	+1·2
9. 6th ,, ,,	Another stool analysed fresh	52·68	0·10	19·40	23·10	0·51	83·97	22·12	..
10. 8th ,, ,,	No. 9 after 48 hours	50·96	0·37	19·6	24·2	1·88	80·98	22·31	+0·2
11. 6th ,, ,,	Another stool analysed fresh	53·40	0·20	17·62	22·7	1·13	77·62	20·92	..

TABLE XIX—*contd.*

No. and date of sample	Description and locality of cane	Juice per cent.	Glucose per cent.	Sucrose per cent.	Total solids	Glucose ratio	Purity co-efficient	Fibre on cane	Increase or decrease on the sucrose
12. 8th March, 1912 .	No. 11 after 48 hours .	50·4	0·38	18·9	23·9	2·01	79·07	25·3	+1·28
13. 12th ,, ,, .	Another stool analysed fresh	52·4	0·14	17·97	21·6	0·78	83·1	24·63	..
14. 13th ,, ,, .	No. 14 after 24 hours . .	51·2	0·9	17·86	23·4	5·06	76·33	20·35	—0·11
15. 12th ,, ,, .	Another stool analysed fresh	49·7	0·15	18·89	22·7	0·79	83·24	23·01	..
16. 13th ,, ,, .	No. 15 after 24 hours .	53·7	0·13	20·06	24·1	0·64	83·28	22·48	+1·17
17. 12th ,, ,, .	Another stool analysed fresh	51·4	0·14	18·68	21·8	0·74	85·69	22·6	..
18. 14th ,, ,, .	No. 17 after 48 hours . .	46·8	0·597	21·06	25·3	2·84	83·24	22·8	+2·38
19. 12th ,, ,, .	Another stool analysed fresh	54·1	0·11	19·92	23·8	0·55	83·7	23·74	..
20. 14th ,, ,, .	No. 19 after 48 hours . .	47·0	0·58	21·89	27·3	2·64	80·34	28·22	+1·97
21. 12th ,, ,, .	Another stool analysed fresh	50·1	0·18	19·31	23·4	0·92	82·5	25·88	..
22. 13th ,, ,, .	No. 21 after 24 hours (paraffined and analysed)	51·2	0·18	20·5	24·6	0·86	83·37	23·81	+1·19
23. 12th ,, ,, .	Another stool analysed fresh	50·6	0·096	19·67	23·9	0·48	82·31	23·26	..
24. 13th ,, ,, .	No. 23 paraffined and analysed after 24 hours	51·0	0·102	20·92	25·1	0·48	83·35	22·42	+1·25
25. 12th ,, ,, .	Another stool analysed fresh	55·3	0·103	18·98	23·1	0·54	82·17	21·74	..
26. 14th ,, ,, .	No. 25 paraffined and analysed afer 48 hours	49·7	0·407	20·17	25·3	2·02	79·71	21·91	+1·19
27. 12th ,, ,, .	Another stool analysed fresh	51·1	0·19	18·08	22·9	1·06	78·98	26·34	..
28. 14th ,, ,, .	No. 27 paraffined and analysed after 48 hours	50·7	1·04	17·38	25·6	6·00	67·91	24·35	—0·70
	Samples of local Dhaulu, Government Farm, Gurdaspur.								
29. 10th February, 1912 .	One stool analysed fresh .	56·66	0·46	15·53	18·7	2·96	83·04	15·82	..
30. 11th ,, ,, .	No. 29 after 24 hours .	59·5	0·67	15·16	18·2	4·41	83·3	16·90	—0·37
31. 10th ,, ,, .	Another stool analysed fresh	55·7	0·90	14·74	18·0	6·1	81·88	19·27	..
32. 11th ,, ,, .	No. 31 after 24 hours . .	59·4	0·89	14·57	18·2	6·10	80·05	15·58	—0·17
33. 12th ,, ,, .	Another stool analysed fresh	51·6	0·69	13·68	17·2	5·04	79·5	19·77	..
34. 14th ,, ,, .	No. 33 after 48 hours (ends cut off)	56·8	0·33	15·15	18·5	2·17	81·9	19·33	+1·47
35. 12th ,, ,, .	Another stool analysed fresh	56·7	0·65	13·55	17·7	4·79	79·5	15·25	..
36. 14th ,, ,, .	No. 35 analysed after 48 hours (ends cut off)	58·0	0·12	14·5	18·5	0·83	78·4	16·95	+0·95
37. 12th ,, ,, .	Another stool analysed fresh	51·6	0·69	13·68	17·2	5·04	79·5	19·77	..
38. 14th ,, ,, .	No. 37 analysed after 48 hours (ends not cut off)	54·9	0·25	14·28	17·6	1·75	81·14	19·24	+0·60
39. 12th ,, ,, .	Another stool analysed fresh	56·7	0·65	13·55	17·7	4·79	76·5	15·25	..
40. 14th ,, ,, .	No. 39 analysed after 48 hours (ends not cut off)	56·3	0·09	14·69	18·8	0·61	78·14	17·04	+1·14

Some loss in weight was bound to occur. The resulting concentration of sugar in the juice can be discounted by comparing the ratio of sucrose to total solids before and after storing. The remaining sixteen samples show an increase in sucrose varying from 2 to 2·4 per cent. This result is important, and has been followed up in a separate series of investigations to be published shortly.[1] It offers an explanation for the above-mentioned country practice of storing cane before crushing. It affects the results given in the tables of district cane analysis to an extent of about minus 0·34 per cent. of sucrose in 20 per cent. of the samples stored for the above period, and plus 1·1 per cent. sucrose in 80 per cent. of the samples. This error is not a serious one in view of the variations bound to occur in the method of taking small samples. Where paucity of staff did not admit of the full analysis of the bagasse at the time of crushing, this was preserved by the addition of a small quantity of chloroform to a previously weighed mass of bagasse enclosed in a stoppered bottle. This was found effective in checking enzymic hydrolysis of the sucrose or other fermentative changes for the period required to despatch these bagasse samples to the central laboratory at Lyallpur.

In collecting the samples, the Assistant in charge of the work supplied the following information :—

(1) Date of sampling : (2) tahsil and village : (3) name of grower : (4) date of sowing the crop : (5) class and description of cane : (6) class of soil on which the cane was growing : (7) an estimate of the canes attacked by borer or disease.

On receipt of the samples in the laboratory the analyst recorded the number of the sample, the average length of 10 canes, the average length of the internodes of 10 canes and the average thickness of the canes between the nodes.

These latter figures were collected as bearing on the growth of the cane and the effect of the season on this.

These figures will be found in the tables giving the average composition of the different types of cane grown in the district at pages 48-54 below.

2. The composition of the different types of canes grown for the seasons 1911-12 – 1915-16.

The examination of the district canes commenced in January 1911, and has been continued both in the district and at the Gurdaspur experimental station or both, up to the present season. The district samples were taken from selected villages throughout the Gurdaspur and Batala tahsils where the best cane is grown. For the practical purpose of the enquiry, it was very necessary for us to consider the best

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[1] *Agri. Jour. India,* vol. XII, part II.

and average cane cultivated in the district, and for this reason we have not extended the enquiry to include the poorer canes of the Bet or of the Pathankot tahsil.

Katha or Chan.

Local information. A thin reddish cane—very hardy—great tillering powers—considerable ability to withstand drought, flooding, and to a less extent frost. Ripens earlier than any other variety. Leaves are very persistent and it is consequently a difficult cane to strip. The rind is hard, and so the cane is not used for chewing. The juice is not of good colour, but is much liked for drinking as it is said to be healthy compared with *Dhaulu* juice, which, though a nice white colour, produces an excess of saliva in the mouth after drinking. The juice is small in quantity compared to other varieties, but contains a good percentage of sugar.

This variety is said to have arisen from the wild "Kahi" grass, which grows in swampy lands in the submontane tracts.

The *gur* from this variety is said to keep better than *gur* of other varieties. A good crop yields 30 maunds *gur* per acre.

Distribution. The most universally grown of any variety in the Province, it is found—

(1) Extensively grown under *barani* (rain-fed) conditions in submontane tracts, where the rainfall, though moderate, is insufficient for other varieties.

(2) Under well and canal irrigation in the submontane tracts some distance from the hills.

(3) In low lands along river and canal banks and on the borders of swamps, where the absence of drainage prevents other varieties from growing. In these localities *rab* is generally made, as the crop never properly ripens.

(4) In the canal colonies in the southern districts of the Province as it withstands the hot dry climate better than other varieties.

TABLE XX.

Dimensions of Katha *cane grown in the Gurdaspur District.*

	1911-12	1912-13	1913-14
Number of observations on which the following figures are based.	1,080	220	9
Average length of cane	4′ 8·3″	4′ 10·7″	4′ 2″
Average length of internodes . . .	3·49″	3·69″	3·3″
Average thickness of internodes . .	0·44″	0·45″	C·40″

TABLE XXI.

Composition of cane in the Gurdaspur District. Variety Katha.

Year	Month	No. of analyses for which the average has been struck	Juice per cent. (on cane)	Analysis: Glucose	Sucrose	Total solids	Glucose ratio	Purity co-efficient	Fibre on cane
				(Per cent. in juice)			(Glucose × 100) / Sucrose	(Sucrose × 100) / Total solids	
1911-12	January	65	55·62	0·68	16·35	19·44	4·16	84·10	20·50
	February	29	56·38	0·51	17·71	20·23	2·31	87·41	20·23
1912-13	December	1	60·8	0·42	16·62	20·08	2·52	82·77	21·36
	January	12	61·9	1·27	16·37	19·91	7·75	82·22	20·64
	February	9	58·75	0·38	17·86	21·78	2·13	82·00	21·53
1913-14	November	1	56·24	2·80	12·75	18·80	21·96	67·81	21·31
	December	3	56·47	1·03	16·53	20·45	6·29	80·83	22·57
	January	6	54·92	1·40	15·33	19·36	9·13	79·18	20·11
	February	5	57·50	0·38	16·53	20·04	2·30	82·48	20·70
1914-15	November	1	60·3	0·26	14·29	17·47	1·84	81·8	21·63
	December	3	56·5	0·64	14·54	18·05	4·41	80·55	21·75
	January	3	60·4	0·46	15·40	18·79	3·00	81·09	21·24
	AVERAGE	138	57·98	0·85	15·86	19·53	5·36	81·02	21·13
	Highest	..	61·90	2·80	17·86	21·78	21·96	87·41	22·57
	Lowest	..	54·92	0·26	12·75	17·47	1·84	67·81	20·11

Dhaulu of Gurdaspur.

Local information. Green when unripe, the cane becomes a white colour, as its name implies, on ripening. It is thicker than *Katha* and requires a better soil and a more liberal supply of water. Occasionally found under *barani* conditions but is nearly always irrigated. It ripens later than *Katha*. Leaves strip off easily. Rind is softer than *Katha*. The sets at planting time are more prone to white ant attack than those of *Katha*. This applies to all varieties in the Province. The thicker the variety the more prone to white ant attack it appears to be. The *gur* is a better colour and the sugar made from it whiter than from *Katha*. The *gur* is reported to be inferior in keeping qualities to that of *Katha*.

Distribution. It is confined to irrigated land in Gurdaspur and adjoining districts. Outside of that tract it is seldom found and does not appear to thrive anywhere so well as in the Gurdaspur District.

This cane and *Tereru* are occasionally found growing in Jullundar. Ludhiana and Ambala districts as mixture in crops of *Dhaulu of Phillour.* There is no difference made between them and they are both known as *Ghorru* and are disliked as they are said to yield very inferior juice.

TABLE XXII.

Dimensions of Dhaulu *cane grown in the Gurdaspur District.*

	1911-12	1912-13	1913-14
Number of observations on which the following figures are based.	760	340	20
Average length of cane	4′ 6·2″	5′ 0·5″	5′ 0·5″
Average length of internodes . . .	2·89″	3·41″	3·27″
Average thickness of internodes . . .	0·52″	0·56″	0·38″

TABLE XXIII.

Composition of cane in the Gurdaspur District. Variety Dhaulu.

Year	Month	No. of analyses for which the average has been taken	Juice per cent. (on cane)	ANALYSIS					
				Glucose	Sucrose	Total solids	Glucose Ratio	Purity co-efficient	Fibre on cane
				(Per cent. in juice)			Glucose × 100 / Sucrose	Sucrose × 100 / Total solids	
1911-12	January .	46	55·52	0·57	16·48	18·88	3·45	87·29	20·75
	February .	35	55·54	0·41	16·11	19·03	2·54	84·65	19·37
1912-13	December .	4	58·93	1·27	13·91	17·52	9·13	79·39	20·24
	January .	16	61·61	0·88	15·81	18·96	5·57	83·38	19·04
	February .	15	59·50	0·27	17·31	20·48	1·56	84·52	20·21
1913-14	November .	2	59·80	3·36	11·25	16·85	3·00	66·77	18·18
	December .	6	60·15	0·39	14·15	17·29	2·75	81·84	19·41
	January .	6	57·34	1·10	13·98	17·37	7·87	80·48	20·17
	February .	14	58·10	0·52	14·68	17·51	3·54	83·83	19·69
1914-15	November .	1	61·1	0·41	13·87	16·63	2·94	83·40	16·82
	December .	4	57·47	0·62	12·74	15·66	4·87	81·35	18·07
	January .	3	62·2	0·41	14·55	17·43	2·81	83·47	19·87
1915-16 .	January .	32	60·72	2·62	10·22	15·01	25·60	68·1	15·99
	AVERAGE .	184	59·07	0·99	14·23	17·59	5·82	80·65	19·06
	Highest .	..	62·20	3·36	17·31	20·48	25·60	87·29	20·75
	Lowest .	..	55·52	0·27	11·25	15·01	1·56	66·77	15·99

Teru or Tereru.

Very like *Dhaulu* of Gurdaspur, but with ivory markings. In Gurdaspur District, where it is very commonly found as a mixture in *Dhaulu* of Gurdaspur, it is looked upon as a fairly good quality cane, and the presence or absence of markings is said to be a question of weather conditions. Sometimes a crop from typical *Teru* seed will in the next year show no ivory markings. On the whole *Dhaulu* is preferred to *Teru* in the Gurdaspur District. In parts of Jullundar, Ludhiana and Ambala districts, it is found much less commonly as a mixture in "*Dhaulu of Phillour*" crops. Generally the ivory markings are present, but occasionally they are absent, when the cane is identical with *Dhaulu* of Gurdaspur. In both cases, however, the cane is known as *Ghorru* or *Ekkar* and is much disliked, as it is said to yield very inferior juice and the best cultivators discard it when they are cutting sets for seed. In the Samrala tahsil of Ludhiana District sometimes the markings are very heavy indeed.

TABLE XXIV.

Dimensions of Teru *or* Tereru *cane grown in the Gurdaspur District.*

	1911-12	1912-13	1913-14
Number of observations on which the following figures are based.	80	30	2
Average length of cane	3′ 8·4″	5′ 2″	4′ 10″
Average length of internodes . . .	2·66″	3·54″	3·35″
Average thickness of internodes . . .	0·53″	0·45″	0·49″

TABLE XXV.

Composition of cane in the Gurdaspur District. Variety Teru (Tereru).

Year	Month	No. of analyses for which the average has been struck	Juice per cent. (on cane)	Analysis: Glucose (Per cent. in juice)	Sucrose (Per cent. in juice)	Total solids (Per cent. in juice)	Glucose Ratio (Glucose × 100 / Sucrose)	Purity co-efficient (Sucrose × 100 / Total solids)	Fibre on cane
1911-12	January .	6	60·13	1·05	15·68	18·23	6·70	86·01	19·66
1912-13 .	..	..	..	..	..	..	..	..	..
1913-14 .	November .	1	58·31	1·37	13·32	16·20	10·28	82·22	21·78
	December .	2	59·28	0·99	14·93	17·94	6·63	82·11	22·35
	January .	4	56·76	0·95	15·16	18·26	6·63	83·02	19·94
	February .	1	57·01	0·62	15·36	17·68	4·04	86·88	19·91
	AVERAGE .	14	58·30	0·99	14·89	17·66	6·69	84·31	20·73
	Highest .	..	60·13	1·37	15·68	18·26	10·28	86·88	22·35
	Lowest .	..	56·76	0·62	13·32	16·20	4·04	82·11	19·66

Kahu.

A green cane, becoming a paler green on ripening, with broad leaves and tall growing habit. The thickest cane in the province from which *gur* is made. Requires better cultivation, better land and more irrigation than other varieties. Is subject to red rot. Ripens very late. Yields very heavily and gives *gur* and *shakkar* of very superior quality. Has a soft rind and is consequently largely used for chewing purposes. Is very susceptible to frost.

Distribution. As a chewing cane it is to be found widely distributed over the Province near towns. As a *gur*-making cane its cultivation is practically confined to the Gurdaspur District, where the conditions are fairly suitable in good and mild seasons.

TABLE XXVI.

Dimensions of Kahu *cane grown in the Gurdaspur District.*

	1911-12	1912-13	1913-14
Number of observations on which the following figures are based.	190	190	8
Average length of cane	4′ 10″	5′ 1·2″	4′ 11″
Average length of internodes	3·31″	3·91″	3·88″
Average thickness of internodes . . .	0·72″	0·65″	0·63″

TABLE XXVII.

Composition of cane in the Gurdaspur District. Variety Kahu.

Year	Month	No. of analyses for which the average has been taken	Analysis: Juice per cent. (on cane)	Glucose (Per cent. in juice)	Sucrose (Per cent. in juice)	Total solids (Per cent. in juice)	Glucose ratio (Glucose × 100 / Sucrose)	Purity co-efficient (Sucrose × 100 / Total solids)	Fibre on cane
1911-12	January .	10	63·42	1·39	14·78	17·90	9·40	82·57	15·08
	February .	5	66·10	0·94	15·09	18·06	6·23	83·55	13·24
1912-13	December .	2	60·25	1·87	12·59	16·06	14·85	78·39	14·48
	January .	12	68·14	1·42	13·80	17·54	10·30	78·68	13·71
	February .	4	71·87	1·77	14·48	18·23	12·22	79·43	12·67
1913-14	November .	1	65·96	4·14	10·75	16·50	38·51	65·16	12·00
	December .	2	67·78	2·01	13·50	17·60	15·00	76·70	13·29
	January .	5	65·64	2·13	12·27	16·41	17·36	74·77	14·95
	February .	5	66·23	1·70	13·20	16·89	12·88	78·15	12·53
	AVERAGE .	46	66·15	1·93	13·38	17·24	14·42	77·61	13·55
	Highest .	..	71·87	4·14	15·09	18·23	38·51	83·55	15·08
	Lowest .	..	60·25	0·94	10·75	16·41	6·23	65·16	12·00

Merthi.

A tall growing thick cane. Very similar in general habit to *Kahu.*

Distribution. Found near towns in the tract where *Suretha* is grown, but, as it is grown only for chewing purposes and on a very small scale, is of little importance.

TABLE XXVIII.

Dimensions of Merthi *cane grown on the Gurdaspur Farm.*

	1912-13	1913-14	1914-15
Number of observations on which the figures are based	5	6	5
Average length of cane	4′ 6″	4′ 6·5″	7′ 0″
Average length of internodes . . .	3·9″	3·33″	4·00″
Average thickness of internodes . . .	0·69″	0·66″	0·66″

TABLE XXIX.

Composition of cane on the Gurdaspur Farm. Variety Merthi.

Year	Month	No. of analyses for which the average has been taken	Analysis: Juice per cent. (on cane)	Glucose (Per cent. in juice)	Sucrose (Per cent. in juice)	Total solids (Per cent. in juice)	Glucose Ratio	Purity co-efficient	Fibre on cane
1912-13 .	December .	1	67·4	2·15	12·53	17·32	17·15	72·35	13·04
	January .	2	69·2	2·62	13·96	18·20	18·77	76·70	13·45
	February .	2	71·45	2·66	15·81	17·41	16·82	90·82	12·45
1913-14 .	December .	2	68·03	2·68	13·21	18·24	20·30	72·42	12·08
	January .	2	66·36	2·12	14·15	17·54	14·98	80·67	12·56
	February .	2	62·82	1·04	16·74	18·50	6·21	90·48	14·64
1914-15 .	November .	1	66·3	2·32	8·51	12·51	27·22	68·00	16·34
	December .	2	67·3	2·36	8·61	12·74	27·40	67·60	11·76
	January .	1	69·4	1·38	12·93	16·34	10·71	79·1	13·31
	February .	1	68·9	1·35	13·14	16·34	10·27	80·4	13·06
	AVERAGE .	16	67·72	2·17	12·96	16·51	16·74	78·5	13·27
	Highest .	..	71·45	2·68	16·74	18·50	27·40	90·82	16·34
	Lowest .	..	62·82	1·04	8·51	12·51	6·21	67·60	11·76

Kansar.

Local information. A tall growing thick red cane of the *Katha* type, approaching the thickness of *Suretha.* Requires good land and more abundant water supply than *Dhaulu* of Gurdaspur or Phillour. It ripens late but yields heavily. A good crop is 40 maunds *gur* per acre of excellent quality.

Distribution. Most extensively grown in the submontane tracts where the water supply and land are specially good. Large areas under this cane are grown on canal-irrigated land in the Batala tahsil of the Gurdaspur District where it is known as *Kahu Katha.* It is also found in the submontane tahsils of Jullundar and Ludhiana districts, where it is known by the names of *Dag Chan* and *Masingen.* Has been seen growing as far south as the Chenab Colony, but this is exceptional. Dries up and becomes pithy in centre unless the water supply is very good.

TABLE XXX.

Dimensions of Kansar *cane grown in the Gurdaspur District.*

	1911-12	1912-13	1913-14
Number of observations on which the following figures are based.	240	170	5
Average length of cane	5′ 6·3″	5′ 0·9″	4′ 5″
Average length of internodes	4·15″	4·32″	3·8″
Average thickness of internodes	0·60″	0·65″	0·59″

TABLE XXXI.

Composition of cane in the Gurdaspur District. Variety Kansar *and* Katha Kahu.

Year	Month	No. of analyses for which the average has been struck	Juice per cent. (on cane)	Glucose	Sucrose	Total solids	Glucose Ratio	Purity co-efficient	Fibre on cane
				ANALYSIS (Per cent. in juice)					
1911-12	January	15	58·48	0·60	16·67	19·51	3·60	85·40	19·75
	February	5	57·00	0·77	17·53	20·01	4·41	87·60	21·18
1912-13	December	1	63·40	0·63	16·08	19·10	3·91	84·37	not analysed.
	January	8	64·54	0·99	15·96	19·32	6·20	82·60	19·19
	February	7	65·37	0·77	17·06	21·22	4·51	80·40	18·47
1913-14	November	1	63·68	2·71	14·05	19·00	19·30	73·94	14·84
	December	1	62·72	1·48	14·95	18·65	9·90	80·19	23·63
	January	5	59·61	1·57	12·75	19·26	12·31	66·20	18·28
	February	3	62·40	1·02	17·37	20·54	5·87	84·56	19·82
1914-15	November	1	61·5	1·20	9·83	14·34	12·20	68·50	21·70
	December	2	60·45	0·61	12·21	16·06	5·00	76·03	18·94
	January	2	62·65	0·54	13·04	17·61	4·14	74·05	19·50
	AVERAGE	51	61·82	1·07	14·80	19·05	7·23	77·69	17·94
	Highest	..	65·37	1·57	17·53	21·22	19·30	87·60	23·63
	Lowest	..	57·00	0·54	9·83	14·34	3·60	66·20	14·84

3. Climatic effect on the composition of the cane juice.

An Indian crop report is always prefixed by an account of the season under review, and in a country where so much depends on the character of the summer rains, the variations introduced into the area under crop and the crop outturn by this climatic factor are extremely wide. Irrigation canals and railways have to a large extent eliminated the famines which in bygone days devastated portions of the country when the rains failed, but the simile of a shower of rain to a shower of gold still holds for North India.

Where the cane is grown under *barani* conditions, that is by rainfall alone, the crop is directly under the weather. Where the rainfall is augmented by well or canal irrigation, climatic variation can be to a large extent neutralized. In a dry hot climate like that of North India, it is very doubtful if irrigation—useful as it is—can adequately replace rain, for one has only to pass through a growing crop after rain to see the difference between its effect and that of irrigation at the same time of the year when the weather is dry. In Hawaii[1] it is stated that young cane requires irrigation water at the rate of $\frac{1}{2}''$ per watering, as it gets well above ground it requires about 1 inch up to 3 or 4 months, after which it requires 1·5 inches until fully grown, when waterings 3 inches in depth are necessary. This is in a climate where the air is warm and moist and rain falls every month.

We have no such figures available for Gurdaspur, and all that can be said here is that in a dry season the cane shows very uneven growth and the system of irrigation by canal is not elastic enough at present to enable the cane grower to adjust his water supply to the crop requirements. Where irrigation from wells is practised, the water supply is more under the direct control of the farmer, but here again he is limited by the cattle at his disposal. In a dry season the crop requires much more water than in one of normal rainfall, for more water is lost by transpiration. To what extent these vary, we do not at present know. It is evident, therefore, that under the best prevailing conditions cane in the Gurdaspur District is very dependent on the summer rains. Any improvement in the elasticity of water distribution during April, May and June will be of help to the cane grower there, and so also will be any improvement in the water yield of the wells and in water-lifting methods. These latter points are receiving the special attention of the Agricultural Department at the present time and the introduction of tube wells and mechanical well lifts gives promise of excellent results.

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[1] Noel Deerr *loc. cit.*

But the cane crop in this district has to face other vicissitudes of climate besides variation in rainfall. Temperature also plays an important part. The cane season commences with sowing in the latter half of March, and the crop is reaped during the following December and January, but the amount of cane remaining uncut at that time is not very great. One of the peculiar practices of cane growing in Gurdaspur is the care exercised by the farmer to preserve his seed. If the winter is mild, the seed cane is left standing in the field. This seldom happens however. For the most part at the first signs of frost he cuts and buries his seed cane, otherwise the seed is spoiled.

A comparison between the seasons of 1911-12 and 1912-13 shows that more rain fell in July, August and September in 1912 and less in October, November and December than in 1911. In spite of the fact that the 1912 rainfall was some 4″ below the average, it was on the whole a better season for cane, for not only was more rain received during the growing of the crop but warm dry weather prevailed during the latter part of the ripening period. In spite of the apparent better season and the more even growth and better appearance of the 1912-13 crop, the average glucose content of the canes was higher, and the sucrose and purity co-efficient lower than in the preceding season of 1911-12. The principal reason for this appears to be a period of frost to which the former crop was subjected in January 1913 which lowered the purity co-efficient of the juice for 2 weeks out of a total of 9 weeks during which the canes were under chemical examination. A close study of the figures reveals the fact that the drier winter of 1912 gave a riper cane than was obtained in 1911, and the crop would have been better all round but for this frosty period.

We shall probably find, as experience is gained, that the district is always subject to this reverse, and even in a good cane season like 1912 when a ripe cane showing even development has been grown, it will still have to face the cold of winter. In this connection a comparison between the Gurdaspur and Lyallpur canes in 1912 is of interest. This is shown in the following table.

TABLE XXXII.

Table showing the highest, lowest and average analyses of all canes examined at Gurdaspur and Lyallpur Stations in 1912-13.

	Glucose (per cent	Sucrose on juice)	Purity co-efficient of juice	Fibre per cent. on cane
		Gurdaspur District.		
Highest	2·81	19·25	94·13	27·97
Lowest	0·09	6·91	60·09	9·51
Average (on 76 samples)	0·72	16·16	82·80	19·44
		Gurdaspur Farm.		
Highest	4·56	19·53	89·58	23·23
Lowest	0·04	7·13	53·40	6·72
Average (on 105 samples)	1·24	15·13	79·30	18·92
		Lyallpur Farm.		
Highest	0·95	18·95	90·5	25·85
Lowest	0·04	12·60	74·10	11·22
Average (on 43 samples)	0·20	15·05	82·30	20·64

In this table are shown the highest, lowest and average analyses of all canes examined at the two stations in 1912-13. From this it will be seen that the sucrose content of the best canes at Lyallpur approximates very closely to the best canes of Gurdaspur, while the worst Lyallpur canes are markedly superior to the worst in Gurdaspur. A comparison of the glucose and purity co-efficient figures shows that here again the advantage lies with Lyallpur. This not only indicates the climatic disadvantages of Gurdaspur, but emphasizes the desirability of even watering for successful cane cultivation, for we have to take into account in this comparison the marked inferiority of the Lyallpur soils to the best soils of Gurdaspur for cane cultivation and of irrigation to natural rainfall.

The ripeness of cane is judged by the ratio of sugar or sucrose to invert sugars calculated as glucose. In unripe cane there is but little sucrose and a comparatively large quantity of glucose sugars. The *glucose ratio* by which the ripeness can be gauged if we are dealing with a known cane is given by $\frac{\text{glucose per cent.} \times 100}{\text{sucrose per cent.}}$. In unripe cane, therefore, the *glucose ratio* is high.

As the cane ripens, the *glucose ratio* falls, and at the same time the total solids in the juice and the sucrose increase, while the amount of

invert sugars diminishes. Both grower and manufacturer aim at producing sucrose, as the other sugars, while of some commercial importance as molasses and for spirit making, are waste products so far as the making of dry marketable sugar is concerned.

In 1913 there was a fall in temperature at Gurdaspur ; frosty nights prevailing from the 6th to 20th January. A large number of canes grown on the Government farm were, therefore, periodically analysed to watch the effects of this fall in temperature on the sugar contents of the juice. The following summarized results were obtained :—

(*a*) There was no marked change in the amount of juice extractable by the Nahan mill as the season advanced between the limits of the experiment, December 15th to February 20th.

(*b*) In all cases there was a steady increase in the total solids of the juice *and this increase was unaffected by frost.*

(*c*) In most cases there was a steady fall in the invert sugars of the juice, except where the cane was affected by frost, when there was in all cases an increase in the invert sugars.

(*d*) In all cases there was an increase in the sucrose content of the juice, except where the cane was affected by frost, when there was usually a decrease in the sucrose contents of the juice, either during or immediately after the frosty period.

(*e*) The *glucose ratio*[1] and *purity co-efficient*[2] are both detrimentally affected by frost, but to a different extent in the different varieties of cane.

The cane varieties were classified in order of merit according to their resistance to the effect of cold, and divided into the following four groups :—

(*i*) *Frost-resistant* (unaffected, or almost unaffected, by cold).

(*ii*) *Semi-resistant to frost, A* (*i.e.*, slowly affected by cold).

(*iii*) *Semi-resistant to frost, B* (*i.e.*, quickly affected by cold but quickly recovering from its effect).

(*iv*) *Non-resistant* (*i.e.*, quickly affected by cold and slowly recovering).

The canes of the district according to this classification fell into the following groups :—

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[1] Glucose ratio = $\frac{\text{glucose per cent.} \times 100}{\text{sucrose per cent.}}$

[2] Purity co-efficient = $\frac{\text{sucrose per cent.} \times 100}{\text{total solids per cent.}}$

TABLE XXXIII.

Classification of district canes according to the effect of cold upon the composition of the juice during season 1912-13.

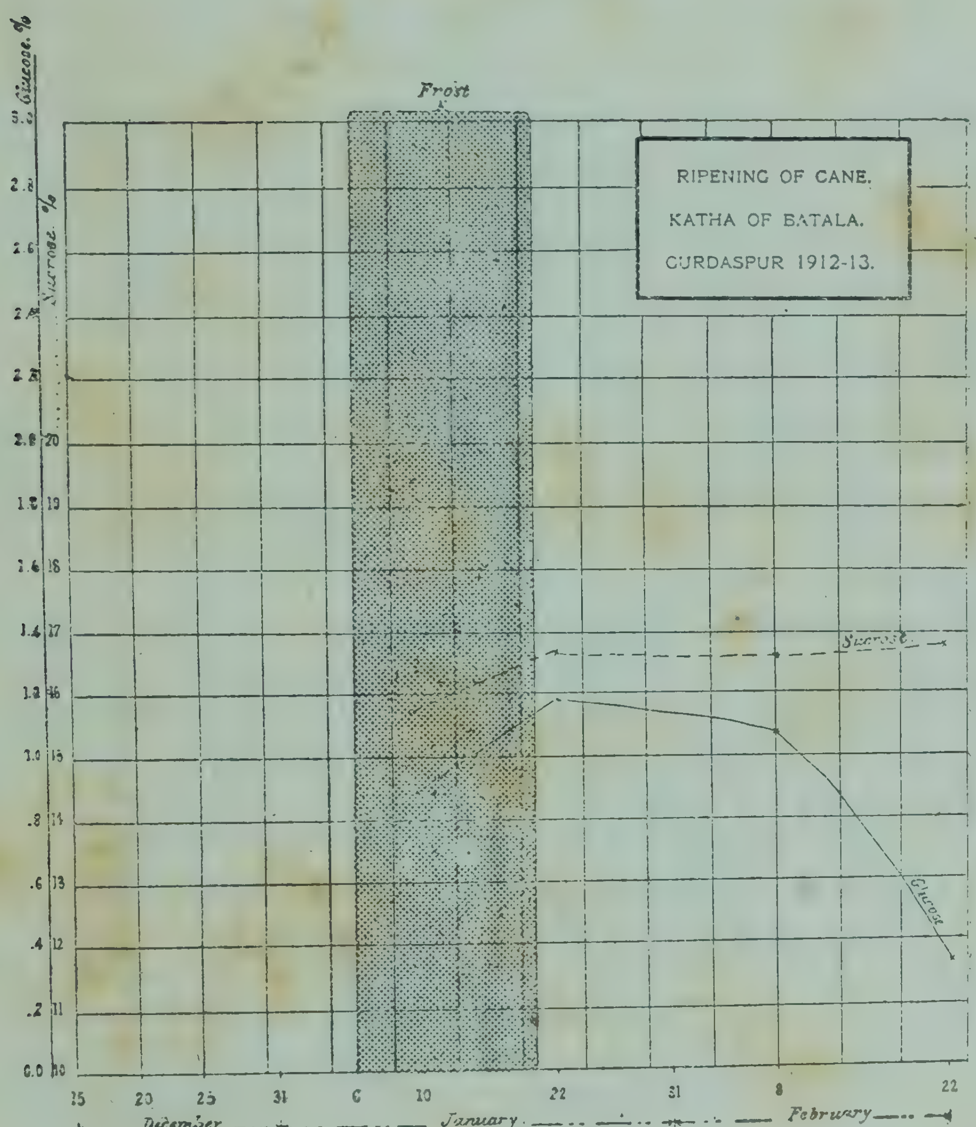
Frost-resistant	Semi-resistant to frost, A	Semi-resistant to frost, B	Non-resistant
1. Katha of Batala	2. Tereru of Batala 3. Kansar of Batala 4. Merthi	5. Kahu 6. Dhaulu	

The analytical results obtained in the case of the above varieties are given in graphic form in the following diagrams :—

DIAGRAM I.

Effect of cold on the chemical composition of cane juice.

Type 1.—Frost-resistant



The enquiry was continued in 1913-14 and 1914-15.

In the season 1913-14, the periods of extreme cold were more intermittent than in 1912-13. Frosty periods occurred from December 26th to December 30th, January 9th, January 22nd to 26th, January 31st and February 9th, while in the season 1914-15 a long cold period occurred in December (December 14—24), January 4—6th, January 13th to 16th, making the season a more severe one.

The district canes were classified according to the above method as follows :—

TABLE XXXIV.

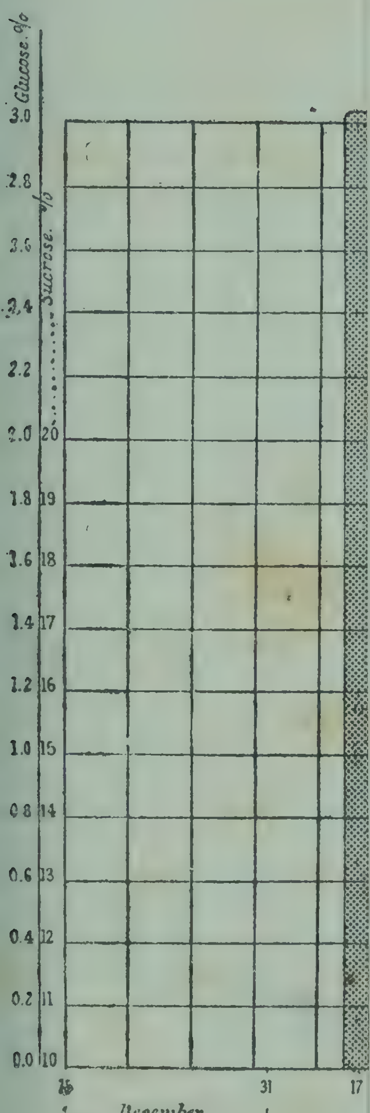
Classification of district canes according to the effect of cold upon the composition of the juice.

Frost-resistant I	Semi-resistant to frost, A II	Semi-resistant to frost, B III	Non-resistant IV
	Season 1913-14.		
Tereru	Katha . .	..	Kahu
Dhaulu	Kansar		
Merthi	Bodi		
	Season 1914-15.		
Kanara	Katha		
Bodi	Kansar		
Merthi.			
Katha (Sept. sown)			
Dhaulu (,,)			

Besides the local canes, this enquiry was extended to include a large number of foreign varieties and the results obtained are in preparation for publication : where the whole question of climatic effect will be more fully dealt with.

These results are of particular importance. They give us at once a key to the sugar problem in the Punjab. No matter how far we may improve cane cultivation by improved methods of tillage or by artificially enriching the soil or how far we supply the natural deficiency of water, we are still faced with this climatic factor of cold which bars the way to progress. There is one narrow opening left in this barrier and that is the selection of an improved variety of cane which is almost or entirely unaffected by the cold to which it will be subjected.

There can be little doubt that the local varieties, such as *Katha*, *Dhaulu*, *Tereru*, etc., have become hardy through long exposure to a severe climate. We do not yet know the types of cane from which these have sprung, but from existing practices in the Southern Punjab where


Glucose %
Sucrose %
December

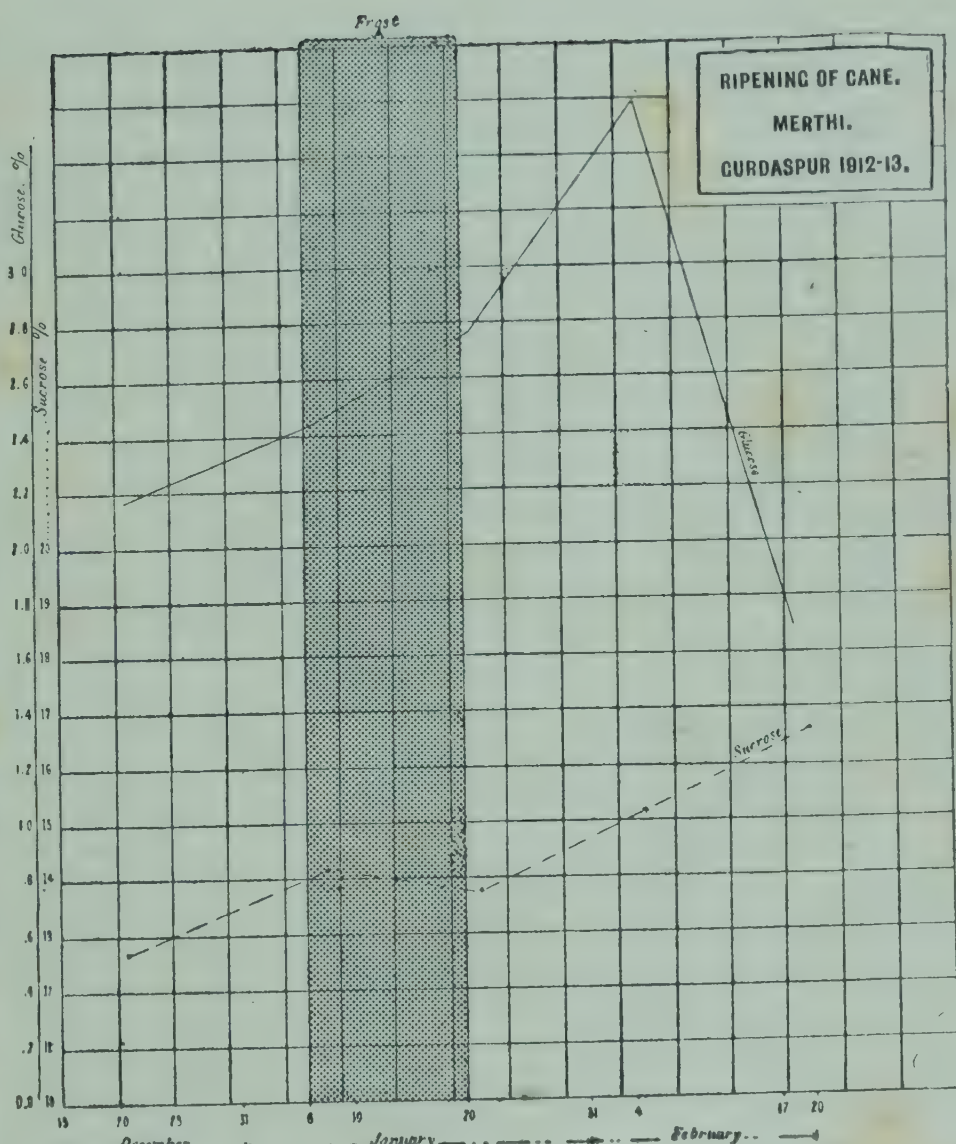
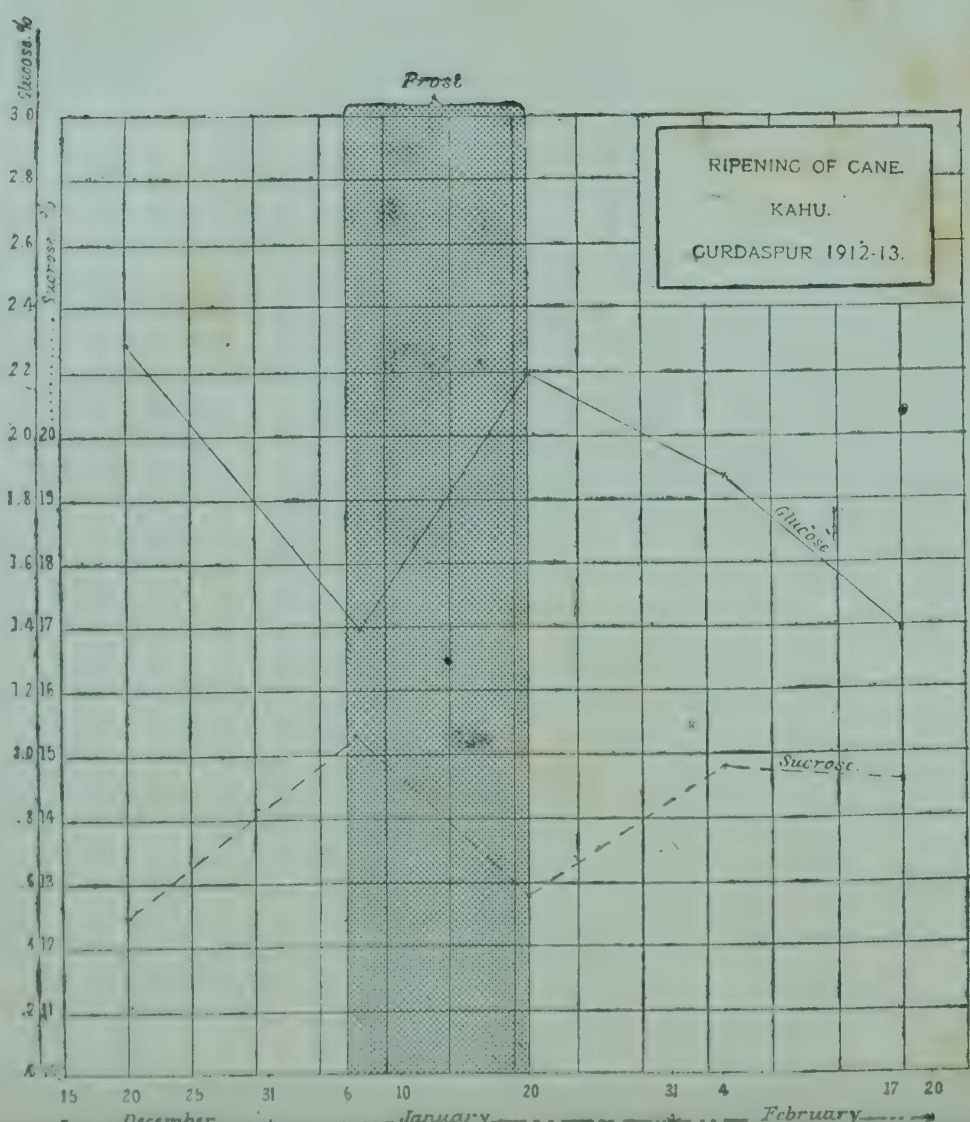
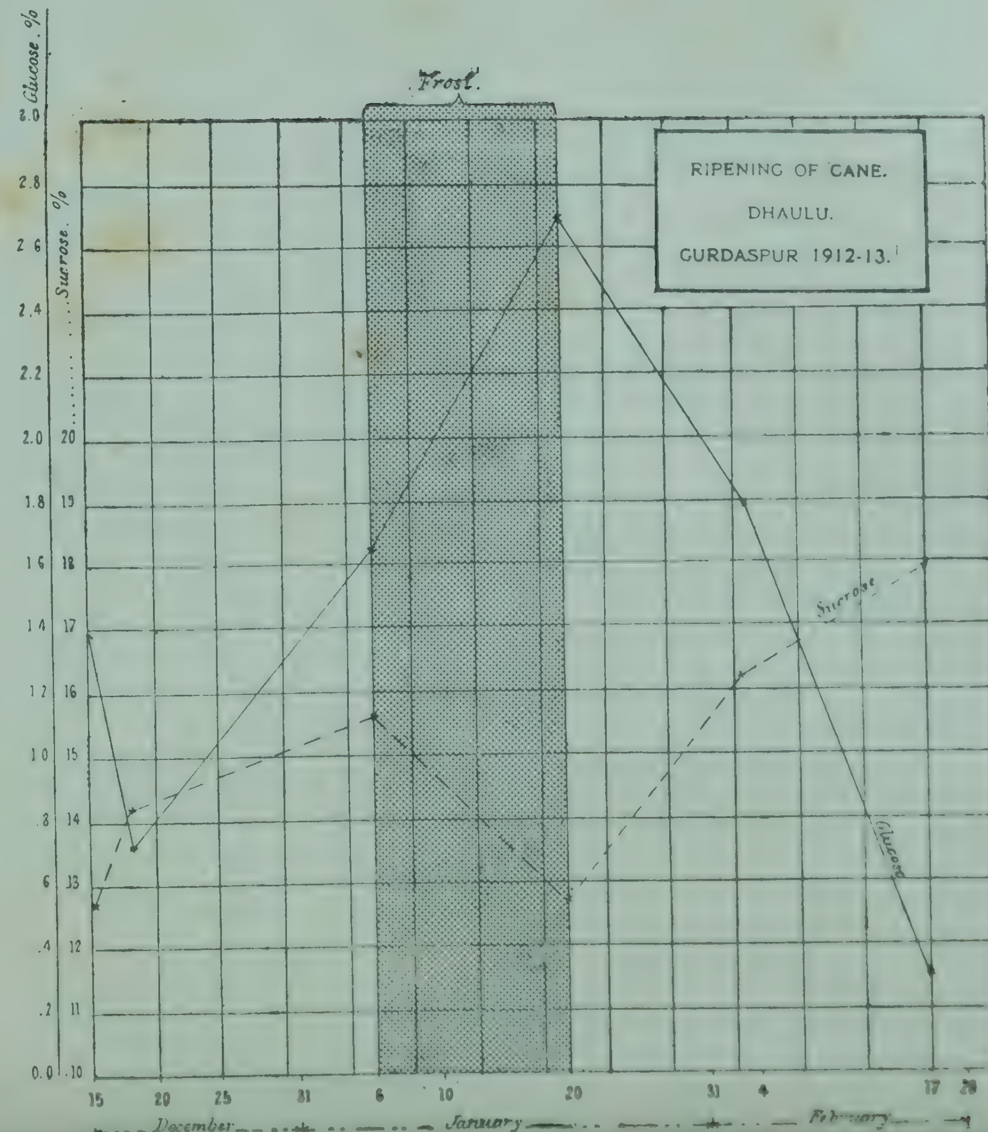

Frost
RIPENING OF CANE.
MERTHI.
GURDASPUR 1912-13.
Glucose %
Sucrose %
Glucose
Sucrose
December
January
February

DIAGRAM III.

Effect of cold on the chemical composition of cane juice.

Type 3.—Semi-resistant to frost B.





the cultivators are in the habit of bringing up seed canes from further south in the United Provinces, it seems most probable that cane cultivation in the eastern portion of the peninsula originated towards the lower end of the Ganges and spread gradually north-west into the regions of greater cold. Within comparatively recent times, *Kahu*—a thick juicy cane—has been introduced into the district from the south and is evidently not yet acclimatized. The out-turns obtained in a good year, however, render this variety attractive to the cultivators who have been accustomed to hard canes of the *Katha* type, and the farmers say that though they may lose the entire crop of *Kahu* every third or fourth year, the gain in the good years recompenses them for the losses so sustained.

For a discussion on the origin of sugar cane, reference may be made to Barber.[1]

[1] Barber, C. A., "Studies in Indian Sugarcanes, No. I." *Mem., Dept. of Agri., India, Bot. Ser,* vol. VII, no. 1, introduction pages 1—5.

CHAPTER IV.

THE SUGAR TRADE IN THE DISTRICT.

1. Total production from Gurdaspur and other districts of the Province.

I shall not attempt to deal with the sugar trade of the Gurdaspur District in anything like a comprehensive manner, for the whole problem of the Indian sugar trade has been fully discussed by Noel Paton [1] and the factors there set out as ruling the importation of foreign sugar into a sugar-producing country like India apply equally to the provincial or even the district problem. In a few words, these are the low cost of production in the countries exporting sugar to India as compared with the cost of production of sugar in India itself, and the ruling factors in the cost of production are yield per acre of sugar and the prevention of waste in manufacture.

In the following table I have given the area under cane for the whole of the district of Gurdaspur, as well as that produced in each tahsil for the past thirteen years as compared with that of the whole Punjab.

TABLE XXXV.

Showing the area in acres under cane for the whole of the district of Gurdaspur as well as that produced in each tahsil for the past 13 years as compared with that of the whole Punjab.

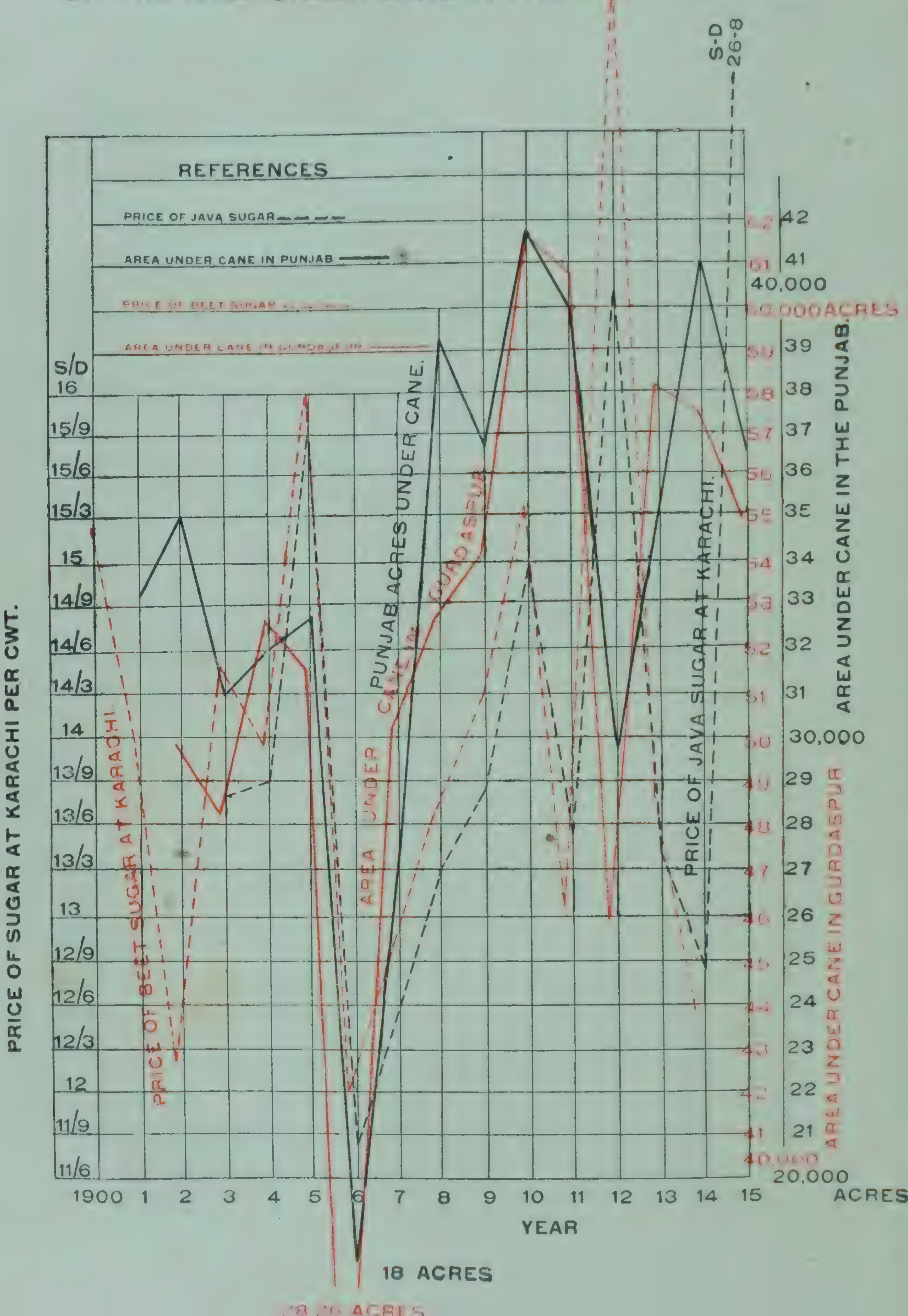
Years	Tahsils				Total for the whole district	Total area for the whole Punjab
	Gurdaspur	Batala	Shakar-garh	Pathan-kot		
1901	16,783	18,192	9,969	4,973	49,917	334,500
1902	17,766	15,660	9,929	4,876	48,231	351,500
1903	17,552	18,366	11,500	5,194	52,612	309,400
1904	16,729	17,154	12,737	4,970	51,590	321,200
1905	9,149	6,283	10,070	2,758	28,260	325,500
1906	16,913	15,399	11,648	4,195	48,155	172,700
1907	15,662	17,182	9,835	4,323	47,002	277,700
1908	18,591	17,702	8,974	5,015	50,282	391,800
1909	21,714	19,801	13,073	5,278	59,866	365,700
1910	20,188	19,614	12,534	4,799	57,135	411,700
1911	13,556	14,887	8,613	3,169	40,225	387,900
1912	18,604	20,803	9,220	4,660	53,287	284,800
1913	20,314	19,889	9,665	4,613	54,481	360,400

[1] Notes on Sugar in India." Government Printing, India, Calcutta.

DIAGRAM IV.

INFLUENCE OF IMPORTED SUGAR

ON THE AREA UNDER CANE IN THE PUNJAB.



This table shows that a considerable variation takes place from year to year in the acreage under cane, not in *barani* tracts alone but also in the land under irrigation. There is, if anything, a greater uniformity in the area under *barani* cultivation, which is contrary to expectation based on the assumption that climatic variations in rainfall influence the area sown (Compare Table 1, Chapter 1, page 2, rainfall in the Gurdaspur District). We must look elsewhere, therefore, for an explanation of these variations.

During a period of ten years, 1906 to 1915, there was a variation of 28 per cent. from the normal in the area under cane in Gurdaspur, the lowest in 1911-12 being 16 per cent. below the average, and the highest in 1909-10 being 12 per cent. above the average.

Compared with that of the whole Punjab, the highest figure for the area under cane was also in 1909-10, when it was 13·7 above the average : the lowest recorded figure being in 1906-07 when it was 23 per cent. below. Next to this in the Punjab figures comes 1911-12, when the average was 18 per cent. below normal. These figures are more intelligible when cast into graphic form.

In the diagram opposite I have not only shown the area under cane, but have, as far as figures are available, included in it the average Karachi prices for beet and Java sugars.

2. Influence of imported beet sugar on cane cultivation in the Punjab.

As we should expect, the Karachi prices for imported sugar rise and fall with the area under cane, this being evidently a case of supply and demand ; the two naturally react upon each other. So far as India alone is concerned, we may regard her demands for sugar as steadily on the increase both because of her growing population and because of her increased prosperity. The area under cane should, therefore, increase, or else if any limit has been set to this by climate, soil, or labour, the yield per acre and the efficiency of the methods of manufacture in vogue should show improvement.

It is true that the substitution of the bullock-driven iron mill has made an advance over the old wooden *belna* in the efficiency of juice extraction, but such a minor improvement is almost negligible when set against the mighty improvements effected in the mechanical methods of sugar extraction in use elsewhere. An examination of the figures shows that in the Punjab the area under cane has not materially increased during the past thirty years or so, for the area in 1884-85 was 335,454 acres, while the average for the past nine years has been 366,779 acres,

and during the latter period has frequently fallen below that of 1884. The area for the whole of India on the other hand has shown an increase. So far as can be gathered from the figures available, this increase has taken place for the most part in the United Provinces. In spite of the increased production which this increase of area under cane indicates, the ratio $\frac{\text{export}}{\text{import}}$ has diminished in every province in the country. During the ten years preceding 1910, there was an almost steady decline in the total area under cane throughout India, which, Noel Paton calculates, was equivalent to a decreased output of 40,800 tons of potential sugar. During this period the imports had risen by 397,000 tons. At the same time the price of imported sugar has fallen from Rs. 10·1 per cwt. in 1899-1900 to Rs. 8·83 per cwt. in 1909-10, while the price of *gur* at Cawnpore has risen from Rs. 5·37 to Rs. 6·75 per cwt., and the declared export value of Madras jaggery from Rs. 4·78 to Rs. 5·4. There is only one feasible explanation for these figures, and this is that imported sugar is either regulating or helping largely to regulate the area under cane in India, for Noel Paton has shown that in the United Provinces, which produces over 50 per cent. of the reported sugar in India, the area under cane has during the ten years following 1900 contracted by some 90,000 acres, while the area under other crops had increased by nearly two millions (or 5·6 per cent. of the whole).

Turning now to the Punjab and especially to Gurdaspur, we see in the diagram given above in graphic form the rise and fall of area under cane and the prices of imported sugar at Karachi, the port for North India.

Any comparison of rainfall figures is difficult as they vary from place to place. The total rainfall for Gurdaspur itself showed a steady increase from 1908 until 1910 and a decrease from 1910 to 1913. The rainfall of any one year cannot, however, affect the area under cane for that year because sowing takes place in the spring, and the bulk of the rain falls in the months of July and August. Its effect, however, is either to improve the conditions and out-turn of the existing summer crops, or to admit of a large area of *barani* cane being sown *the following summer.* We have seen, however, that the *barani* cane area is far more uniform than is that under irrigation. The principal effect of good summer rains then is on the late sown summer and winter crops. *It does not affect the area under cane* except in an indirect manner, *viz.*, the general prosperity of the agricultural classes and a rise in demand and in the price paid for sugar.

If imported sugar can be sold in the bazaars of Northern India cheaper than an indigenous article of equal purity, this is bound to contract the area under cane there to the extent to which the imported article

can replace the natural product. If we compare the value of European beet sugar with East Indian cane sugar imported into India, we see that previous to 1900, beet sugar was commanding a higher price at the western ports than imported cane sugar. This cane sugar came principally from Mauritius. By 1903 Java sugar was competing and selling at a lower price than beet. Since then these two classes have been in competition with the balance in favour of the Java sugar.

Noel Paton sets forth in a very clear manner the strengthening effect of the Austrian cartel on the foreign sugar trade of that country, and the similarly stimulating effect of its imitation by Germany.

At certain periods the Indian import sugar market has been in the hands of a particular producing country. The above quoted prices for beet sugar at Karachi show that, up to the appearance of Java sugar there, the imports were for the most part beet sugar.

The appearance of Java sugar in 1903 introduced a competition, which from the outset has apparently always been able to undersell beet. This is borne out in the figures given for the average annual prices of beet and Mauritius sugar at Bombay, namely, that at the Western Indian ports imported cane sugar can always undersell beet. Between the years 1898 and 1907 the greater part of the sugar imported into Karachi was beet, which for the most part came from Austria-Hungary. By 1908 the imports for cane sugar had grown until the amount exceeded the beet imports. From this it appears that beet sugar sets the price of this article at Karachi and that this price is so favourable that Java sugars can compete in comfort, and are gradually claiming the bulk of the market there. Diagram IV opposite page 63, indicates that the fluctuations in the area under cane in the Punjab as well as in the Gurdaspur District are the result of fluctuations in the imports and prices of foreign sugar—both beet and cane—or in other words *between certain limits*—the limits mentioned on pages 64, and 92-95—*the area under cane in the Gurdaspur District is regulated by the amount and price of imported refined sugar*. This is an important deduction : it shows the precarious nature of the sugar trade in the district, and leads us at once to consider in what manner this external influence may be controlled. The first and what appears the simplest solution, the solution suggested by all previous students of this problem, is to increase and improve the indigenous industry until foreign sugar can no longer compete. I venture to suggest, however, that this may not prove to be economically possible in North India, either now or in the future, and we may have to achieve the result in a somewhat different manner. The facts upon which we have to base our reasoning are, firstly, that foreign sugar can be produced at such a low cost abroad—cane sugar in Java and Mauritius

and beet sugar in Austria-Hungary and Germany—that their excess products can pay freighting into India and to the Indian markets and still undersell the Indian sugar. On the other hand, we have seen the difficulties in the way of improving the cultivation of cane in the Gurdaspur District, and to what extent the climate and conditions there hinder the growth of this crop. I shall refer in the next chapter to the crops now in competition with cane in Gurdaspur. In Egypt, it has been found that cane cannot compete with cotton in Lower Egypt and the Delta, and an existing industry complete with factories and an established cane cultivation had to retire further south when the value of Egyptian cotton became known to the manufacturing world. A comparative study of the history of sugar growing and refining in Egypt is of the greatest interest and importance when considering the problem of cane cultivation in North-West India. The climate here, while unsuited for the growth of high quality cane, is admirably adapted for cotton. *Primâ facie*, therefore, cotton can be improved more easily and with more certainty than can the sugarcane, and we have the example of the industry in Egypt to point the argument that even under climatic conditions equally suitable to either crop, cotton proved to be the stronger. Now the markets for Egyptian cotton are the best on the continent of Europe and in Lancashire, while the market for Egyptian sugar is in Egypt itself.

Indian cotton of the best quality will have to compete in the same markets at any rate for many years to come. It must, therefore, be produced at a lower cost as well as of high quality, if it is to pay the extra freighting and canal dues which it will have to do before it reaches the manufacturer. Such a policy is based on broader lines than the improvement of one crop. We not only aim at raising the out-turn of raw products in the country, but, what is of greater importance still, to the happiness and welfare of India, we must aim at increasing the individual comforts of her inhabitants by increasing their spending power. There has been much foolish talk about the policy of agricultural improvement being to make two blades of grass grow where only one grew before. We can achieve this by intensive cultivation but this does not always result in improving the prosperity and happiness of the classes engaged in agriculture as we can see at a glance if we compare the conditions existing in the congested districts of the Ganges valley with, say, the free farmers of Australia, of the veldt, of the pampas, or even of the canal colonies in North India. The ideal agricultural policy is to lower the cost of production *so that one man can produce with less bodily labour and at less cost what it previously took two or more men to accomplish.* Competition will then regulate the increase of out-turn

of raw produce. If this is accepted, then the climatic factor becomes more and more important and we shall float with the stream rather than row against it.

It does not follow from this that the Punjab must abandon its existing cane industry forthwith and be content to purchase sugar from abroad. India is a big country and there are many places in it where the sugarcane finds a natural home. It is in these places where the cane naturally flourishes that efforts should be made to secure that portion of the Indian market which is or has been up to recently in the possession of the manufacturers of Java, of Austria-Hungary, or of Germany. It is possible to find parts of India where Indian sugar can be produced at a less cost than the price at which foreign sugar has to be sold in India, and it is to the sugar zones in India that Government attention should first be directed in any efforts which may be made to improve this industry and render it independent of foreign influence. As for the existing sugar industry in the Gurdaspur District, and that similarly existing in other parts of the Punjab, we should for the time being limit the effort and money devoted to improving it to checking waste in the existing processes of crushing and boiling, to introducing better canes selected specially with reference to their adaptability to the rigorous climate of Northern India, and to improving the cultivation and yielding power of the land. Apart from this, we should concentrate the main attention of the Agricultural Department in improving those crops more particularly suited to the climate and soil and for which there is a large and growing foreign demand such as cotton, wheat, oilseeds, pulses, etc. The future of the cane industry so far as Northern India is concerned, can be safely left to competition. Southern, Central and Western India will in the course of time produce all the sugar required in Northern India in exchange for the commodities grown there, and at a less cost than it can be produced in the Punjab. Under such natural and healthy competition, cane, which is to be regarded as foreign to the Punjab, will gradually be replaced by other and more remunerative crops. The present high value of cane in Northern India is anomalous. The industry established itself in the days when India possessed no means of inter-communication save roads and those of the worst description and it derives support to-day largely from a sentimental regard for raw country sugar on the part of a portion of the Indian public, and from the fact that sugar boiling provides the farmers with a very pleasant occupation at a cold and idle part of the farming year. This is borne out by an examination of the trade figures for sugar products within the district itself. Gurdaspur is, as we have already stated, the largest producer and grower of sugar in the Province; we should, therefore, naturally expect to find

that there is a large amount of sugar exported from the district and little or no sugar beyond refined sugar imported from outside.

3. Exports of sugar products.

In Table XXXVI I have given a copy of figures supplied by the North-Western Railway for the outward land sugar traffic as booked at the various stations on the Amritsar-Pathankot line, which runs through the whole length of the district. From the table, it will be noticed that the bulk of the trade lies in the Gurdaspur and Batala tahsils, the latter predominating.

TABLE XXXVI.

Showing the outward traffic (in maunds) of sugar booked from North-Western Railway stations in the Gurdaspur District for the years 1911 to 1914.

Name of station	1911-12			1912-13			1913-14		
	Refined sugar	Raw sugar	Gur, rab, or molasses	Refined sugar	Raw sugar	Gur, rab, or molasses	Refined sugar	Raw sugar	Gur, rab, or molasses
Pathankot . .	205	244	549	16	748	426	8	507	795
Sarna . .	..	24	159	..	14	11	2	18	101
Jakhalan . .	..	..	..	..	..	..	..	..	..
Permanand .	..	..	..	..	..	..	..	..	..
Dina Nagar . .	195	281	3,236	..	194	1,179	4	108	1,768
Sohal . .	..	1,451	6,367	..	781	5,620	..	902	9,584
Dhariwal . .	204	777	5,471	..	1,020	2,485	4	772	4,673
Gurdaspur .	111	3,358	37,005	..	6,011	35,947	43	5,344	47,277
Batala . .	293	14,444	148,013	14	46,656	106,960	6,528	25,950	155,077
TOTAL .	1,008	20,579	200,800	30	55,424	152,628	6,589	33,601	219,275

4. Nature of sugar imports.

In Table XXXVII are given the recorded imports of sugar and *gur* for the years 1903 to 1912 compiled from Government records in the office of the Deputy Commissioner, Gurdaspur.

TABLE XXXVII.

Statement showing the imports (in maunds) of sugar and gur *for the years 1903-04 and 1911-12.*

Year	By rail			By river			By rail	By river	Total of Gur, rab, etc.	Grand total
	Refined	Unrefined	Total	Refined	Unrefined	Total	Gur, rab, etc.	Gur, rab, etc.		
1903-04	13,40,562	6,77,877	20,18,439	19,420	..	19,420	10,59,279	..	10,59,279	30,97,138
1904-05	12,01,953	8,09,514	20,11,467	20,830	..	20,830	10,79,156	..	10,79,156	31,11,453
1905-06	21,60,086	8,42,119	30,02,205	25,820	..	25,820	24,57,726	..	24,57,726	54,85,751
1906-07	22,65,050	8,83,845	31,48,895	29,020	..	29,020	13,05,560	..	13,05,560	44,83,475
1907-08	23,25,050	8,73,097	31,98,147	41,340	..	41,340	13,75,780	..	13,75,780	46,15,267
1908-09	20,55,712	7,84,706	28,40,418	38,960	..	38,960	13,62,069	..	13,62,069	42,41,447
1909-10	19,98,285	10,21,230	30,19,515	42,180	..	42,180	12,84,767	..	12,84,767	43,46,462
1910-11	24,90,640	8,47,100	33,37,740	36,950	..	36,950	11,82,846	..	11,82,846	45,57,536
1911-12	19,12,698	15,43,674	34,56,372	34,230	..	34,230	17,87,196	..	17,87,196	52,77,798

The very large amount of imported sugar varying from 30 to over 50 lakhs of maunds of sugar is evidently very largely in excess of the sugar exported. That is to say, that in this, the largest sugar-producing district of the Punjab, the consumption of sugar is largely in excess of the production. This is very interesting because it indicates in yet another manner that the industry is decaying because it is not keeping pace with the growing demand for sugar.

Examining this trade in rather more detail, we find that in the year 1885 (*Assessment Report of the Gurdaspur District* by L. Dane, 1890) the export of sugar was considerably in excess of the imports, and that in the five years following the ratio of $\frac{\text{import}}{\text{export}}$ gradually increased. The importation of sugar into Gurdaspur at that time was probably the result of better trade conditions for sugar there than in the adjoining districts.

TABLE XXXVIII.

Rail-borne traffic for the carriage of sugar through the Gurdaspur District in the year 1885 (Assessment Report, 1890, by L. Dane).

Tahsil	Export		Import	
	Quantity in maunds	Value (rupees)	Quantity in maunds	Value (rupees)
Gurdaspur	70,700	1,76,750	1,092	2,730
Batala	99,540	3,31,800	4,650	15,500
Pathankot	3,780	9,450	1,344	3,360
Shakargarh	(No railway station in the tahsil.)			
Total .	174,020	5,18,000	7,086	21,590

TABLE XXXIX.

Rail-borne traffic for the carriage of sugar through the Gurdaspur District, average of five years 1884—88.

Tahsil	Export		Import	
	Quantity in maunds	Value (rupees)	Quantity in maunds	Value (rupees)
Gurdaspur	52,218	1,30,545	1,795	4,488
Batala	169,556	5,65,187	6,403	21,342
Pathankot	12,918	32,295	3,923	9,808
Shakargarh	(No railway station in the tahsil.)			
Total .	234,692	7,28,027	12,121	35,638

TABLE XL.

Showing the total recorded rail-borne traffic in maunds of sugar and sugar products in the Gurdaspur District in 1907 and 1908 (Gurdaspur Assessment Report by F. Kennaway, 1910).

Year	Raw sugar		Refined sugar		Gur, shakkar jaggery and molasses	
	Export	Import	Export	Import	Export	Import
1907	1,522	23,252	7	13,086	278,573	33,021
1908	2,207	35,081	501	16,750	299,457	33,112

TABLE XLI.

Showing the ratio of import to export of all rail-borne sugar products in Gurdaspur District for the years 1884-88, 1907-08 and 1911-12.

Year	Export Maunds	Import Maunds	Imports to exports
1884-88	234,692	12,121	0·05
1907	277,102	69,359	0·25
1908	302,165	84,943	0·28
1911-12	320,387	5,243,568	16·36

Within the last 30 years or so, the exports of sugar have not increased to anything like the same extent as the imports. For whereas in 1884-85 the ratio $\frac{\text{import}}{\text{export}}$ was 0·05 : 1, in 1911-12 the ratio rose to 16·36 : 1.

We have already seen that the area under cane cultivation has not changed greatly within this period—it fluctuates from year to year, but on the average remains fairly constant. This being the case, and because we have no reason to believe that the out-turn of sugar produced per acre has increased to the extent shown by the increased exports by rail (from 234,692 maunds in 1884-85 to 320,387 maunds in 1911-12), we are forced to the conclusion that this increase is due for the most part to the re-exportation of imported sugar or, if this is not the case, then the increase is indirectly due to imported sugar releasing a larger and larger amount of locally produced sugar for export by replacing the consumption within the district.

The greater part of the exports is in the form of raw sugar, *gur* and jaggery ; the amount of refined sugar going out of the district being very small. On the other hand there has been an enormous increase in the importation of refined sugar. This all bears out the contention that imported refined sugar is an important factor in regulating the area of cane grown.

5. Prices : Factors governing the fluctuation of prices of sugar products.

In 1883 Harcourt (*ibid*) reported that there was no foreign competition in the sugar trade of this district. Foreign sugar—of what kind we do not know—but to the extent of some 7,000 maunds was imported into the district in 1885 two years later.

TABLE XLII.

Prices prevailing in 1883 for the sugars manufactured in the district (Harcourt report [ibid])

Class of sugar product	Average wholesale price	Average retail price
Coarse sugar, *gur*	16½ seers per rupee	16 seers per rupee
Shakkar	11½ „ „	11 „ „
Refined Talouncha khand	6¼ „ „	6 „ „
Khand	4⅛ „ „	4 „ „
Sugar manufactured at the Sujanpore refinery—		Rs. A. P.
Sugar No. 1	10 per cent. less than retail prices	14 8 0 per maund.
„ No. 2		12 12 0 „
„ No. 3		11 4 0 „
Small whole grain		13 4 0 „

The average price of *gur* between 1884-85 in Gurdaspur and Pathankot according to Dane (*loc. cit.*) was 16 seers per rupee, and in Batala 12 seers per rupee ; the latter figure is probably low or the two former figures high, because a close comparison of *gur* prices in Batala with those in Gurdaspur shows the latter to be always slightly higher as we should expect, seeing that Batala tahsil produces far more sugar than Gurdaspur.

The following two tables show the prevailing current prices of *gur* in these two tahsils from 1905 to 1914 month by month. The total average for the last ten years has been 8·04 seers per rupee in Gurdaspur and 8·7 seers per rupee in Batala. Within the last 30 years, raw sugar has *risen* there in value to an extent of 100 per cent. Even allowing for the decreased purchasing value of the rupee as in the ratio of $\frac{24}{16}$, we still find that the value of raw sugar in the last ten years was nearly 55 per cent. higher than it was in 1883.

TABLE XLIII.

Statement of current prices of gur in Gurdaspur in seers per rupee from 1905 to 1914.

Year	January		February		March		April		May		June		July		August		September		October		November		December		Average
	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	
1905 . .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8	8	8	..	8	7	7·6
1906 . .	6½	5½	5½	6	5½	..	5½	6	6	..	6	..	6	..	6	..	6	..	6	8	8	..	8	10	6·4
1907 . .	8	9	10	10	10	..	10	..	9	..	8½	8	8	..	8	..	8	7	7	7	7	..	7½	..	8·3
1908 . .	7½	7½	7½	7½	7½	..	7½	..	7½	7	7	..	7	..	7	..	7	7½	8	..	8	..	9	..	7·5
1909 . .	9½	8½	8½	9½	9½	..	9	8	8	7½	8	..	8	..	8	7½	8	..	8	..	7	..	8½	10	7·9
1910 . .	10	10	10	10	10	..	10	..	9	..	8½	..	8½	..	8½	..	8½	..	8½	..	8½	9	10	..	9·2
1911 . .	10	..	10	..	10	9	8	..	8	..	8	..	8	..	7	..	7	..	7	..	7	..	8	7	8·0
1912 . .	7	..	7	..	7		7	..	7	6	6	..	6	..	6	..	6	..	6	..	6	7	9	10	6·8
1913 . .	9	..	9	..	9	..	9	..	9	..	9	..	9	..	9	..	9	..	9	..	9	..	9	..	9·0
1914 . .	9	..	10	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	9·7
AVERAGE FOR 10 years.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		..	8·04

TABLE XLIV.

Statement of current prices of gur *in Batala in seers per rupee from 1905 to 1914.*

Year	January		February		March		April		May		June		July		August		September		October		November		December		Average
	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	
1905 . .	12	..	11½	10	10	9½	8	..	9	..	8	9	8	9	8½	..	10	..	7½	..	7½	..	8½	7½	9·0
1906 . .	7½	7	6½	6½	6½	7½	7	7	6½	7	6	6	7	6½	6½	6½	8	6½	7	7	7	11	10	10	7·2
1907 . .	10	10	10	10	10	10	10	10	10	9	8	8	8	8	8	8	8	8	8½	8	8	..	10	10	9·0
1908 . .	10	10	10	8	8	8	8	8	8	8	8	8	9	9	9	9	9	9	9	9	9	9	8	8	8·7
1909 . .	9½	9½	9½	..	9½	..	9½	..	10	9½	9½	..	8½	..	7	..	7½	..	7½	..	6	..	8	..	8·0
1910 . .	10	..	10	..	10	..	10	..	10	..	10	..	10	..	9	..	10	..	10	..	10	..	11	..	10·0
1911 . .	10	8½	8½	..	8½	..	8½	..	8½	..	8½	..	8½	..	8½	..	8½	..	8½	..	8½	..	7	..	8·5
1912 . .	6½	..	6½	..	8½	..	7	..	7	..	6	..	7	..	7	..	7	..	8	..	8	..	7	..	7·0
1913 . .	10	..	8	..	8	..	8	..	8	..	8	..	10	..	10	..	10	..	10	..	10	..	10	..	9·2
1914 . .	10	..	11	..	10¼	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10·3
AVERAGE FOR 10 YEARS.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8·7

We can only account for this by the increased prosperity of the district resulting in a greater demand for sugar which has been met almost entirely by imports from outside the district.

This indicates the early stages of a decay of the industry foretold earlier in this chapter. *Gur* (which is the form of sugar still most commonly used) is evidently produced cheaper in the south than it can be made in Gurdaspur where the cost of its production is regulated by the value of the other raw stuffs grown in the district. These have evidently increased in value to a greater extent than has the sugarcane, hence the gradual invasion of this stronghold of the Punjab cane industry by foreign sugar, and by foreign I mean anywhere outside the district of Gurdaspur.

We shall see this importation of foreign sugar into the district increase in the future and I anticipate in the course of time a shrinkage in the area under cane. There need be no cause for alarm, provided at the same time we see that the value of the exports from this district and the area under other crops show a steady and corresponding increase. It is evident to me that the fight for the sugar trade of India will have to be borne by those parts of the country which fall naturally in the sugarcane zone, that is, where the cane has not to face the climatic disadvantage to which it is subjected in the Punjab and especially in the Gurdaspur District.

CHAPTER V.

IMPROVEMENT OF THE EXISTING INDUSTRY.

1. Low yields of cane : A consideration of the various causes contributing to this result.

Many of the economic limits to the improvement of the cane industry in the Gurdaspur District have been indicated in the preceding chapters. Some of these limits are beyond control at present, others are under partial control, while the remainder constitute what we might term immediately remediable defects in the industry. I will try and follow this classification in the following pages, though such a classification is of necessity purely arbitrary—what are to-day regarded as limitations beyond human control, may in a few years' time when more exact knowledge is available, be possibilities, and to-day's probabilities be to-morrow's certainties. Such a classification will serve as a useful point to take off from, in considering how far the existing industry can be improved. Perhaps the first and most apparent defect is the low yield of cane obtained throughout the district. In spite of the time which has elapsed since cane appeared—so far back that we have no positive record of how long ago it is since this first took place—the farmer has not yet succeeded in achieving an improvement of the crop at all comparable with the improvements effected among other cane-growing peoples elsewhere : and indeed we have very good reason to believe that cane has degenerated rather than improved. This is not because the crop has received little or no attention from the Punjab peasant, for the proverbs of the people are rich in reference to the many details of land preparation and treatment essential to the growing of a good crop of cane. The variations in yield even within the district itself show that better cane can be grown than is generally the case, and more of it per acre. The insistence of the agricultural proverbs such as given in the foot-note [1] shows to what extent this depends on suitable soil conditions, and these proverbs are but typical of many others to be heard

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[1] *Punjab Agricultural Proverbs* edited by Maconochie.

Page 93—Atthais báh, giyárah páni, nau khod. Jab dekhe ganne ka lod. (If you plough 28 times, water 11 times and weed 9 times, you may look for good sugarcane.)

Page 96—Máh Phágan ki khori, sher ki jhori. (Ploughing in Magh and Phágan is like the scratch of a tiger, *i.e.*, very effective.)

Page 98—Mail de, sor raja kiya de. (The Raja cannot give what manure gives to the soil.)

throughout the district. We are not justified, therefore, in assuming that the backwardness of the industry is due to lack of attention on the part of the farmer. To what then can we attribute the general unsatisfactory condition of the crop ? Apart from the climate, I believe it is largely due to the poor implements at his disposal, and this is particularly effective in a crop like cane which makes such heavy demands upon the soil. The Punjab peasant can in all justice be said to have solved the greater part of the agricultural problems capable of solution by the means at his disposal. The Indian farmer is just beginning to obtain implements and tools of steel, and we have only to look at the history of American agriculture—to take one example only—to see what cheap steel has done for farming in that country. With better transport facilities, better and cheaper implements will gradually find their way into every Punjab village. This is one of the main lines of improvement being now advocated by the Punjab Agricultural Department and with the best of results. The effect of this will be better outturns in all crops due to better methods of tillage—deeper ploughing and a more effective use of the power available to the farmer. This constitutes one of the first, greatest, and most effective improvements available, and will operate advantageously on all crops.

On the more economical use of water, I have at present little more to say than has been already stated above in Chapter I. The cultivators using well irrigation for cane, having to raise this water themselves, practise every reasonable economy in its use and in the prevention of undue losses by evaporation from the soil. The prevention of waste of water by weeds or by unsatisfactory methods of tillage is part of the regular propaganda of the Agricultural Department, and, whenever possible, implements are being introduced to facilitate this objective.

Draining. There is a considerable amount of land in the district which could be improved by draining ; land which at present is either unfit for cane or only grows the poorest quality. This aspect of the agricultural improvement might well engage the attention of the irrigation expert, for the excess of water so recovered would be of great value in the arid tracts further west. At present land is lying waste in Gurdaspur because of excess of water, while not far away there is land equally valueless on account of insufficient water. A more even distribution should be possible with beneficial results.

Among other improvements in the growing of the cane, which are unlikely to yield immediate results, may be mentioned improvements in the varieties of cane grown, and the restoration of the full fertility of the partially exhausted soils of the district by the application of artificial manures.

As regards the first of these, *viz.*, the introduction of improved varieties of cane, reference may be made to tables given below in which is given a record of the cane variety trials carried out at the Gurdaspur Experimental Farm during the past four years. These experiments have so far failed to indicate a foreign cane as hardy as the indigenous canes of the district, and the extended use of these canes would, therefore, have to include arrangements for bringing in fresh seed from further south every few years. I question whether this is likely to be remunerative and hesitate to recommend it at this stage. If, in the course of further study of these and other canes, we find one hardy enough to withstand the rigorous climate of Gurdaspur and better in yielding powers and in purity and richness of juice than the indigenous varieties, we should of course at once proceed with its distribution to the zemindars, but there seems no immediate hope of achieving this. If frost-resistant canes of high quality can be easily produced by breeding or by selection this would have been done long ago in Louisiana where there is an old established sugar industry. The unstable condition of the industry there may be gauged, however, from Table II. taken from a report in the *Indian Trade Journal*, vol. XXXIV, no. 438, page 308-09, dated August 20, 1914.

TABLE XLV.

Cane variety trials, Gurdaspur, 1912-13.

Name of variety	Date of sowing	Actual weight of cane reaped	Actual weight of juice obtained	Actual weight of gur obtained	Weight of cane per acre	Weight of juice per acre	Weight of gur per acre	Agricultural notes
		Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Deep ploughed 8"
Dhaulu	20th March, 1912	146 25	85 30	11 32	439 35	257 10	35 16	Harrowed 3 times. 750 mds. of farmyard manure per acre. Watering . 4 Hoeing . 3 Harrowing . 1
Suretha	Ditto	62 4	39 20	6 20	398 25	253 22	41 29	
Dhaura of Azamgarh	Ditto	38 21	22 4	2 37½	548 16	314 24	41 33	
Cawnpuri	Ditto	18 20	9 30	1 28	443 10	227 24	40 29	
Lal, hard	Ditto	19 29	11 20	1 19	542 17	316 10	40 21	Ordinary ploughing with Rajas. Harrowing 3 460 mds. of farm-yard manure per acre. Watering . 3 Hoeing . 3 Harrowing . 1
Reora of Benares	Ditto	34 25	17 30	2 28	602 33	309 1	47 0	
Merthi	Ditto	15 5	9 20	1 16	366 1	286 5	42 14	
Chin	Ditto	64 14	34 20	5 38	479 35	257 11	44 8	
Patarki Mango	Ditto	9 39	5 10	6 31	439 37	228 36	33 31	
Tereru of Batala	Ditto	16 37	7 10	1 15	680 5	278 19	52 32	
Katara	Ditto	4 13	2 4	0 11	455 2	220 38	28 37	
Barhai	Ditto	39 2	22 0	3 22	547 32	308 25	49 32	
Katha of Batala	Ditto	23 3	13 5	2 20	351 8	199 30	38 2	
Kansar of Batala	Ditto	31 10	16 10	2 38	570 30	305 37	53 35	
Dhaulu	24th March, 1912	733 3	409 15	58 33	324 8	181 2	26 0	

TABLE XLVI.

Cane variety trials, Gurdaspur, 1913-14.

Name of variety	Area harvested in square yards	Weight of cane	Weight of juice	Weight of gur	Weight of shakkar	Weight of cane per acre	Weight of juice per acre	Weight of gur per acre	Percentage of juice to cane.	Percentage of gur to juice	Percentage of gur to cane	Percentage of shakkar to juice
		Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.				
Dhaulu of Bham	1,493	117 0	54 0	9 12	..	379 11	175 2	30 6	46·15	17·22	7·83	..
Katha of Batala	1,493	80 12	38 30	7 10	..	260 13	125 25	23 20	48·24	18·70	9·02	..
Tereru of Batala	1,514	112 31	59 20	9 10	0 21	360 21	190 8	31 10	52·72	16·37	8·66	17·5
Kansar	1,504	69 29	37 20	7 25	..	224 15	120 27	24 22	53·78	20·33	10·93	..
Kahu	1,499	83 33	46 20	7 20	..	270 26	150 6	24 9	55·47	16·12	8·94	..
Lal, hard	1,501	88 37	43 0	8 30	..	286 30	138 26	28 9	48·35	20·34	9·83	..
Reora of Benares	1,522	90 18	51 0	0 22	7 27	287 25	162 7	26 6	56·37	18·33	9·09	15·98
Suretha	1,507	74 10	38 10	7 31	..	238 19	122 33	24 39	53·31	20·32	10·82	..
Barha	1,513	76 1	37 0	6 27	..	243 8	118 14	21 14	48·66	18·04	8·78	..
Dhaura of Azamgarh	1,522	96 37	47 0	..	8 7	308 9	149 18	26 0	48·49	..	8·43	17·39
Behar	205	16 31	7 0	1 10	..	396 2	165 11	29 20	41·72	17·85	7·45	..
Mango	209	11 15	5 0	1 0	..	263 16	115 32	23 6	43·95	20·00	8·79	..
Matki Mango	214	13 27	7 0	1 13	..	309 11	158 12	29 39	51·18	18·93	9·59	..

Chin	207	16 7	6 20	1 14	..	378 8	151 39	31 23	40·18	20·77	8·39	
Betakali of Dumraon . .	269	12 4	5 5	..	0 33	269 14	92 9	14 34	42·36	..	6·81	16·09
Katara	174	5 38	3 10	0 12½	0 10	165 20	90 16	15 26	54·62	17·85	9·45	16·60
Matna	439	22 6	12 30	2 20	..	244 8	140 23	27 23	57·56	19·60	11·28	..
Merthi	230	16 38	6 35	1 10	..	356 27	144 27	26 12	40·56	18·18	7·37	..
Manch of Basali. . .	270	14 25	6 0	1 10	..	258 16	107 22	22 16	41·52	20·83	8·54	..
Desi Suretha . . .	223	18 38	10 0	2 5	..	411 12	217 1	46 5	52·77	21·25	11·21	..
Patarki Mango . . .	265	15 7	8 20	0 10	1 10	277 6	155 10	27 16	56·05	16·66	9·88	17·71
Bodi	217	24 17	11 0	1 32	..	544 31	245 14	40 7	45·03	16·36	9·21	..
Dhaura Kanar . . .	262	25 20	13 20	2 10	..	471 3	249 0	41 22	52·94	16·66	8·82	..
Dhaulu Suretha . .	280	23 36	13 20	2 0	..	413 5	233 14	34 23	56·47	14·81	8·36	..
Kanara	218	20 26	9 0	1 20	0 11	458 10	199 32	38 23	43·58	20·00	8·41	18·33
" selected . .	68	3 31	2 10	0 18	..	268 28	160 6	32 1	59·6	20·00	11·92	..

TABLE XLVII.

Cane variety trials, Gurdaspur, 1914-15.

Name of variety	Area harvested in square yards	Weight of cane	Weight of juice	Weight of gur	Weight of shakkar	Weight of cane per acre	Weight of juice per acre	Weight of gur per acre	Weight of shakkar per acre	Percentage of juice to cane	Percentage of juice to gur	Percentage of gur to cane	Percentage of shakkar to juice	Percentage of shakkar to cane
		Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.					
Lal, hard	771	50 29	29 28	4 8	1 1	318 17	190 13	32 27	33 12	58·55	17·54	10·43	17·83	10·12
Kanara	985	51 33	32 0	..	5 19	254 26	157 10	..	26 36	61·74	..	..	17·11	10·56
Bodi	889	70 22	38 0	..	5 39	384 4	206 35	..	32 32	53·86	..	..	15·72	8·46
Dhaulu of Bham	545	47 6	25 0	..	3 27	418 6	222 0	..	32 25	55·02	..	..	14·70	7·8
Kahu	782	93 6	59 35	7 19	..	576 21	370 23	46 10	..	64·28	12·48	8·02	..	..
Reora of Benares	864	106 13	62 32	4 26	4 12	595 25	351 34	53 29	46 31	59·06	15·28	9·02	13·28	7·84
Kansar	1,074	98 3	61 15	9 15	..	441 39	275 26	42 10	..	62·57	15·27	9·55	..	..
Merthi	1,100	97 9	61 35	7 39	..	427 31	272 10	35 4	..	63·64	12·88	8·2	..	..
Suretha	778	71 29	41 21	6 39	..	446 8	258 13	43 15	..	57·89	16·79	9·7	..	..
Dhaura of Azamgarh	549	48 14	21 39	..	3 18	426 10	193 29	..	30 17	45·45	..	..	15·69	7·13
Tereru	1,060	93 32	53 26	7 20	0 9	428 12	242 38	35 9	36 12	57·19	14·38	8·22	15·0	8·57
Chin	1,072	93 14	54 38	8 25	..	421 18	248 4	38 38	..	58·85	15·69	9·24	..	..
Matki Mango	1,107	94 26	59 10	9 0	..	413 33	259 4	39 14	..	62·59	15·19	9·51	..	..

Katha of Batala	904	60 7	34 16	5 26	..	322 7	184 7	30 10	..	57·16	16·42	9·36	..	
Katara	441	30 8	17 27	0 18	2 2	331 18	193 39	29 2	27 5	58·52	15·0	8·78	13·97	8·16
Betakali of Dumraon	509	45 30	25 16	..	3 26	435 1	241 21	..	34 28	55·52	..	..	14·37	7·97
Patarki Mango	396	41 27	20 18	0 39	1 37	509 14	249 37	37 18	34 20	49·07	15·0	7·36	13·18	6·78
Barhai	560	46 32	25 28	2 22	1 13	404 19	222 5	33 36	32 29	54·91	15·27	8·37	14·72	8·09
Mamch of Basati	529	61 10	33 0	4 11	..	560 15	301 37	39 5	..	53·88	12·95	6·98	..	..
Sanachi of Dumraon	499	55 7	33 0	0 16	4 7	535 7	320 3	43 1	44 21	59·81	13·33	8·0	13·91	8·32
Behar	810	36 22	22 0	3 5	..	570 26	343 19	48 32	..	60·19	14·20	8·55	..	..
Sunnabille	535	62 38	36 30	5 32	..	569 19	332 19	52 19	..	58·38	15·78	9·21	..	..
Mango	823	111 18	55 0	4 15	3 20	655 18	323 18	47 6	45 12	49·32	14·58	7·19	14·0	6·91
Desi Suretha	1,130	108 21	64 8	9 29	..	464 33	274 37	41 26	..	59·15	15·15	8·96	..	..
Dhoura	1,102	116 38	70 9	8 2	..	513 26	308 17	35 14	..	60·05	11·46	6·88	..	..
Kinar	1,049	66 19	41 1	4 23	..	306 28	189 11	21 4	..	61·71	11·15	6·88	..	..
Dhaulu Local	2,098	208 30	118 39	14 0	..	481 23	274 18	32 12	..	56·99	11·74	6·7	..	..
,, Saretha	240	24 11	14 18	1 37	..	489 21	291 16	38 33	..	59·53	13·32	7·93	..	..
Katha (cross-drained)	225	11 29	7 10	0 36	..	252 9	155 34	19 14	..	61·83	12·41	7·59	..	..
Dhaulu (winter sown)	255	20 5	11 38	1 20	..	381 39	226 33	24 19	..	59·38	·12·55	7·45	..	..
Dhaulu (cross-drained)	714	64 24	39 0	4 24	..	437 36	264 15	31 7	..	60·37	11·79	7·12	..	..

TABLE XLVIII.

Cane variety trials, Gurdaspur, 1915-16.

Name of variety	Area harvested in square yards	Weight of cane	Weight of juice	Weight of gur	Weight of cane per acre	Weight of juice per acre	Weight of gur per acre	Percentage of juice to cane	Percentage of gur to juice	Percentage of gur to cane
		Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.			
Sonabchi	771	69 28	43 0	5 30	437 16	269 36	36 4	61·70	13·38	8·25
Behar	840	95 30	62 2	8 21	551 24	357 20	49 4	64·8	13·74	8·90
Suretha	840	59 1	40 20	4 39	340 4	233 12	28 26	68·61	12·28	8·43
Lalri	2,148	135 22	86 24	12 19	305 24	195 4	28 4	63·86	14·41	9·20
Dhaura of Azamgarh	974	84 36	46 25	6 0	421 32	231 28	29 33	54·93	12·86	7·07
Reora of Benares	888	60 1	39 5	4 29	327 8	213 8	25 30	65·18	12·08	7·84
Mango	810	58 13	31 5	4 16	348 20	186 0	26 12	53·37	14·14	7·54
Bodi	2,280	146 13	86 10	10 7	310 24	183 4	21 24	58·95	11·80	6·95
Patarki mango	2,280	208 18	119 25	13 29	442 28	253 36	29 6	57·36	11·48	6·59
Kathā	610	45 7	25 30	4 7	358 20	204 12	33 5	56·99	16·21	9·24
Kathā	898	77 11	48 20	5 19	416 16	261 12	29 20	62·76	11·29	7·09
Katarā	1,060	65 18	45 26	5 37	298 32	208 16	27 2	69·76	12·98	9·05
Kanarā	1,950	144 33	86 10	9 34	359 12	214 4	24 18	59·58	11·42	6·803
Tereru	212	17 29	10 5	1 7	404 32	231 8	26 33	57·12	11·61	6·628
Chin	206	18 17	10 30	1 18	432 36	252 20	34 2	58·34	13·49	7·87
Kansar	112	8 5	3 29	0 18	351 8	161 0	19 18	45·83	12·08	5·538
Nargori	72	4 6	2 22	0 14	278 36	171 16	23 2	61·45	13·73	8·435
Khari	105	6 0	4 32	0 20	276 24	221 8	23 2	79·98	10·42	8·33

TABLE II.

Sugar industry in Louisiana, 1911-13.

Year	No. of factories	Average yield of cane per acre	Average sugar made from acre cane	PER MILL AVERAGE		Average length of the campaign in days
				Sugar made	Cane milled	
		Short tons	Pounds	Short tons		
1911 . .	188	19	2,200	1,877	31,315	..
1912 . .	126	11	1,500	1,219	17,163	30
1913 . .	153	17	2,300	1,913	27,542	45

This supposition is borne out by the system in vogue in the Southern Punjab of bringing in seed cane every few years from the United Provinces. The experience of the local farmers has evidently taught them the advantage of this and the impossibility of establishing a good hardy cane by acclimatization without the cane undergoing degeneration. In 1913 five hardy varieties of cane were planted in the autumn in order to see if the young plants could survive the winter better than the mature canes, and so secure a more certain harvest by lengthening the growing season. The experiment was a failure and only *Katha* and *Dhaulu* varieties survived. The out-turns of *gur* were :—

Katha—19 maunds and 14 seers per acre.

Dhaulu—28 maunds and 19 seers per acre.

The analyses of the Gurdaspur soils quoted in Chapter I indicate the impoverished nature of the land there and the probability of improvement by the addition of artificial manures. The use of artificials, however, is by no means a simple matter. If it is to be effective and remunerative, it is necessary first to work out by field trial the best combination of manures required by the soil. This is always done, and the chemical analysis of soil will not do more than point the way and indicate the more glaring deficiencies. Every year there is more and more evidence accumulating that a biochemical analysis as well as a chemical analysis is required to assist in forming an opinion about the cropping qualities of the soil, but at the present time the biochemical methods at our disposal are extremely scanty and there is a lack of data. In order to secure the required information on the manurial needs of the Gurdaspur soils manurial experiments were commenced at Gurdaspur in 1915. It is too early yet to pass any opinion on these as several years' results will be required before this can be done, but the out-turns obtained are given below :—

TABLE L.

Statement showing the results of manurial experiments with sugarcane (Local Dhaulu) in F. No. 2, 1915-16.

No. of plot	Harvested area in square yards	Treatment	Weight of cane	Weight of juice	Weight of gur	Weight of cane per acre	Weight of juice per acre	Weight of gur per acre	Percentage of juice to cane	Percentage of gur to juice	Percentage of gur to cane
			Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.			
1	866	Untreated	71 15	44 24	5 17	398 36	249 8	30 13	62·47	12·16	7·6
2	1,006	Lime=2,000 lb. per acre; Ammonium sulphate=200 lb. per acre.	81 28	58 29	6 31	393 4	282 24	32 24	71·88	11·53	8·29
3	1,047	Untreated	91 26	55 23	8 8	423 28	256 36	37 36	60·64	14·75	8·94
4	897	Potassium sulphate =200 lb. per acre; Superphosphate=200 lb. per acre.	86 17	53 20	6 15	466 12	288 28	34 16	61·90	11·91	7·37
5	1,047	Lime=2,000 lb. per acre; Ammonium sulphate=200 lb. per acre; Potassium sulphate =200 lb. per acre; Superphosphate=200 lb. per acre.	86 23	48 5	6 9	400 12	222 20	28 31	55·59	12·93	7·19
6	1,047	Potassium sulphate =200 lb. per acre; Superphosphate=200 lb. per acre.	84 9	52 20	7 26	389 20	242 32	35 15	62·33	14·57	9·08
	1,047	Untreated	88 36	56 0	7 38	411 4	258 36	36 30	62·93	14·20	8·94

8	1,047	Lime=2,000 lb. per acre; Ammonium sulphate=200 lb. per acre	71 1	46 20	6 30	329 20	215 0	31 8	65·27	14·52	9·473
9	1,047	Untreated	89 32	51 19	7 31	415 12	238 4	35 38	57·33	15·10	8·66
10	1,047	,, ...	86 30	44 6	7 20	401 8	204 4	34 27	50·89	16·99	8·64
11	1,047	Lime=2,000 lb. per acre; Superphosphate =200 lb. per acre	97 20	58 20	8 18	450 32	270 20	39 3	60·01	14·44	8·67
12	1,047	Untreated	80 39	48 20	6 34	374 16	224 12	31 27	59·89	14·13	8·46
13	1,047	Potassium sulphate, 200lb. per acre; Ammonium sulphate, 200lb. per acre	89 31	54 20	6 28	415 8	252 0	30 36	60·70	12·29	7·46
14	1,047	Lime=2,000 lb. per acre; Potassium sulphate=200 lb. per acre; Ammonium sulphate=200 lb. per acre; Superphosphate =200 lb. per acre	88 4	50 10	6 29	407 16	232 16	31 4	57·03	13·39	7·63
15	1,047	Potassium sulphate=200 lb. per acre; Ammonium sulphate=200 lb. per acre	76 3	45 28	6 30	351 32	211 12	31 8	60·06	14·77	8·87
16	1,047	Untreated	79 0	39 30	5 38	365 12	183 32	27 20	50·31	14·27	7·53
17	1,047	Lime=2,000 lb. per acre; Superphosphate =200 lb. per acre	92 19	48 18	7 15	427 28	224 0	34 4	52·37	15·23	7·98
18	1,047	Untreated	97 36	54 0	8 3	452 28	249 28	37 14	55·16	14·96	8·25

TABLE LI.

Analysis of the Gurdaspur farm canes, 1915-16. Manurial experiments.

No.	Date of sample	Description and locality of cane	Juice						
			Juice per cent.	Glucose per cent.	Sucrose per cent.	Total solids	Glucose ratio $\left(\frac{\text{Glucose}\times 100}{\text{Sucrose}}\right)$	Purity co-efficient $\left(\frac{\text{Sucrose}\times 100}{\text{Total solids}}\right)$	Fibre on cane
1	10th January, 1916 .	Dhaulu, unmanured Plot 18, Field 2, Government Farm, Gurdaspur	58·91	0·49	15·17	18·40	3·23	82·47	19·82
2	Ditto .	Ditto	61·67	1·33	12·72	16·58	10·44	76·68	18·59
3	12th January, 1916 .	Dhaulu, unmanured Plot 9, Field 2, Government Farm, Gurdaspur	57·98	0·43	15·59	18·54	2·79	84·09	16·41
4	Ditto .	Ditto	57·19	1·54	12·78	16·84	12·02	75·90	11·99
5	Ditto .	Ditto	62·99	2·83	5·45	11·07	51·84	49·26	10·07
6	21st January, 1916 .	Dhaulu, unmanured Plot 1, Field 2, Government Farm, Gurdaspur	60·66	2·93	5·02	10·04	58·37	50·05	14·60
7	Ditto .	Ditto	56·67	2·72	10·78	15·66	25·24	68·85	16·68
8	Ditto	Ditto	58·64	2·66	11·78	16·52	22·55	71·29	17·06
9	13th January, 1916 .	Dhaulu fully manured (with N+K+P+Ca), Plot 14, Field 2, Government Farm, Gurdaspur	59·78	1·11	15·11	19·08	7·35	79·21	20·03
10	Ditto .	Ditto	63·87	2·97	4·91	10·61	60·53	46·26	14·60
11	Ditto	Ditto	59·20	0·85	15·90	19·66	5·32	80·83	20·01
12	Ditto .	Ditto	58·64	3·09	8·88	14·20	34·83	62·56	18·24
13	17th January, 1916 .	Dhaulu fully manureed (with N+K+P+Ca), Plot 5, Field 2, Government Farm, Gurdaspur	58·86	3·39	10·96	15·78	30·92	71·12	17·83
14	Ditto .	Ditto	53·96	4·41	5·18	11·83	85·02	43·82	14·73
15	Ditto .	Ditto	67·47	3·95	5·96	12·04	66·18	49·55	10·64
16	Ditto .	Ditto	64·28	3·32	6·49	12·09	51·25	53·67	12·50

TABLE LI—*concld.*

Analysis of the Gurdaspur farm canes, 1915-16. Manurial experiments.

No.	Date of sample	Description and locality of cane	Juice: Juice per cent.	Juice: Glucose per cent.	Juice: Sucrose per cent.	Juice: Total solids	Juice: Glucose ratio $\left(\frac{\text{Glucose} \times 100}{\text{Sucrose}}\right)$	Juice: Purity co-efficient $\left(\frac{\text{Sucrose} \times 100}{\text{Total solid.}}\right)$	Fibre on cane
17	14th January, 1916 .	Dhaulu, manured with nitrogen and potash, Plot 13, Field 2, Government Farm, Gurdaspur	60·75	3·62	7·42	12·49	48·75	59·40	17·49
18	Ditto .	Ditto	61·28	3·21	10·98	16·01	29·25	68·61	17·11
19	Ditto .	Ditto	62·33	2·64	9·83	14·76	26·81	66·64	13·86
20	Ditto .	Ditto	64·86	2·30	12·00	16·70	19·14	71·88	15·52
21	20th January, 1916 .	Dhaulu, manured with nitrogen and lime, Plot 2, Field 2, Government Farm, Gurdaspur	64·45	2·55	8·36	12·77	30·54	65·43	16·39
22	Ditto .	Ditto	62·79	2·68	10·14	14·69	26·38	69·02	10·95
23	Ditto .	Ditto	65·52	2·17	11·28	15·39	19·23	73·28	13·19
24	Ditto .	Ditto	63·06	2·78	9·74	14·34	28·56	67·97	12·63
25	19th January, 1916 .	Dhaulu, manured with phosphorus and potash, Plot 4, Field 2, Government Farm, Gurdaspur	62·02	2·41	10·98	15·18	21·95	72·36	19·38
26	Ditto .	Ditto	63·06	4·07	8·76	14·76	46·51	59·34	13·47
27	Ditto .	Ditto	57·73	1·46	13·46	17·06	10·83	78·91	21·13
28	Ditto .	Ditto	61·73	3·29	10·13	15·53	32·53	65·19	16·40
29	16th January, 1916 .	Dhaulu, manured with phosphorus and lime, Plot 11, Field 2, Government Farm, Gurdaspur	52·67	1·35	14·77	18·72	9·12	78·91	21·52
30	Ditto .	Ditto	65·00	3·42	7·70	13·39	44·44	57·54	11·87
31	Ditto .	Ditto	59·14	3·43	7·36	12·99	46·63	56·62	16·35
32	Ditto .	Ditto	55·89	4·43	11·56	16·72	38·33	69·16	20·68

From the appearance of the crop and from the analysis of the juice, it was evident that excessive vegetative growth and consequent retardation of ripening had taken place. This may have been due to too much manure or to its application at the wrong time. I am inclined to think that the latter was the case, and that the manure should be put in with the crop immediately preceding cane so as to ensure that the young cane gets the greater part of the benefit to be derived from it. The growing season is so short in this district that any lengthening of the growing period will be detrimental. This is probably one reason for the local custom of avoiding excessive manuring of cane lands. The successful use of artificials is likely to be a delicate and difficult operation, and we do not yet know where the limitations lie. In the case of cane, climate will probably prove to be the chief restriction because of the danger attending late ripening.

A considerable amount of further information will have to be sought in field trials in this direction before we can recommend a suitable method of artificially correcting the manurial deficiency of the Gurdaspur soils. In the meantime better methods of cultivation, giving a deeper soil in which to grow the crop, will be effective.

For the information of growers of cane in Northern India, who are interested in this manurial experiment, I give below a sketch of the ground plan of the experiment.

1 U.	4 K.P.	7 U.	10 U.	13 K. N.	16 U.
2 N. Ca	5 K.P. N.Ca	8 N. Ca	11 P.Ca	14 P.Ca K.N.	17 P. Ca
3 U.	6 K.P.	9 U.	12 U.	15 K.N	18 U.

U = Unmanured.
P = Superphosphate 200 lb. to the acre.
Ca = Lime 2,000 lb. per acre.
K = Potassium sulphate 200 lb. per acre.
N = Ammonium sulphate 200 lb. per acre.

The plots are 1,047 square yards each except plots Nos. 1, 2 and 4 which are 866, 1,006 and 897 square yards respectively in extent and are each separated by a ditch and two rows of cane. In the experiment given above, the manure was applied at the time of sowing. In the next season the manure will be applied with the preceding maize crop in the

rotation maize *senji*—sugarcane—wheat. Other experiments have been tried at Gurdaspur, such as surrounding the cane fields on three sides with a ditch 3 feet in depth to ensure adequate drainage and aeration. The advantages have not so far been apparent. The Java system of planting and of preparation of the land for planting is likewise under trial, but so far there are no results to report.

2. Extension of area under cane.

There is more cane grown in Gurdaspur than in any other district in the Province, as may be seen by reference to Table XXXV, page 62, Chapter IV. Of the submontane districts of the Punjab, Gurdaspur enjoys the best irrigation facilities and this is certainly one of the principal reasons why so much cane is still grown there. It is found growing practically in every village in the district, and is still considered by the zemindars to be the most remunerative crop grown. It is said to pay the revenue of the district. Under existing conditions, the area under cane cannot be extended without unduly interfering with the rotations at present in vogue. The possibilities of increasing the area under cane will be regulated by the water supply available and by the labour which can be got for harvesting.

The canal-irrigated lands probably grow as much cane as there is manual labour for its management, and any extension would therefore necessitate either the importation of labour or the reorganization of the existing labour and the introduction of labour-saving devices and machinery. The industry is not in a sufficiently flourishing condition to support this, nor is there any immediate prospect of it becoming so. Wherever water can be cheaply raised by the Persian wheel, cane is already grown. To increase the area under cane by increasing the irrigation facilities means improvement in the existing system of well irrigation. An increased supply of irrigation water is a sound proposition, whether it is to be used for cane or other crops, and steps are being taken to sound the water resources of the district, to improve the wells and to cheapen the supply of water for farm lands by a better and cheaper system of water-lifting. We look to the subsoil water of the Gurdaspur District to supply us with all the additional water required, rather than to an increase in the supply of canal water, as this could only be given at the expense of other districts further west and would moreover only tend to increase the area of waterlogged lands. In this respect Gurdaspur by virtue of its geographical position is well served and there is an abundance of water within easy reach of the surface.

In this connection, it may be noted that, in the Punjab, canal irrigation has resulted in a considerable rise of subsoil water table, so much

so indeed that in certain tracts there is danger of the land becoming waterlogged owing to seepage water escaping from the canals. An interesting experiment is being made by the Irrigation Department at Amritsar where the water table has risen to within six feet of the surface. In this experiment, electric power generated from canal water power is being used for irrigation by pumps—the distribution of canal water over the area now under pump irrigation being either entirely or partially discontinued. The experiment is an important one and will be watched with great interest by agricultural specialists, as well as by irrigation engineers and by Government, as, if successful, it will solve one of the greatest problems in North-West India. In examining the possibilities of increasing the area under any one crop, we have to consider the other crops in competition.

3. The crops in competition with cane.

As might be expected, the area under cane in such a district as Gurdaspur is subject to considerable seasonal variation. I have shown in Chapter IV that the variation appears to be controlled by external influences, one at least of which, and one of the most important, being the price of foreign sugar at the Punjab seaport (Karachi).

In planting cane or other crops, the farmer is naturally guided to some extent by the ruling market prices of his produce, and he will sow as much as he can of the crop which promises to give him the best return for his outlay in land, labour and capital : this can react but slowly to market prices, however, a considerable time must elapse between seed time and harvest and in a conservative country like India, this all tends to keep down the price and value of raw produce. The depression of prices is maintained by the comparatively high railway freightage rates and by the fact that the district exports only raw material, and has to import all, or practically all, the manufactured products used there. In this respect, it is a small competitor with the rest of India and the world, and is not in a position to make its influence felt. Any change will, therefore, be slow.

I have summarized the crop returns for the 12 years ending 1913 for the four tahsils of the Gurdaspur District in Tables V—VIII, Chapter I, pages 10-12. These results are given in graphic form in diagrams V to VIII.

These graphs show that there is a considerable variation from year to year in the area under the different crops, and that there is no apparent relationship between the amount sown, that is to say, if the area under cane declines there is no equivalent increase in the area under cotton or rice.

DIAGRAM V.

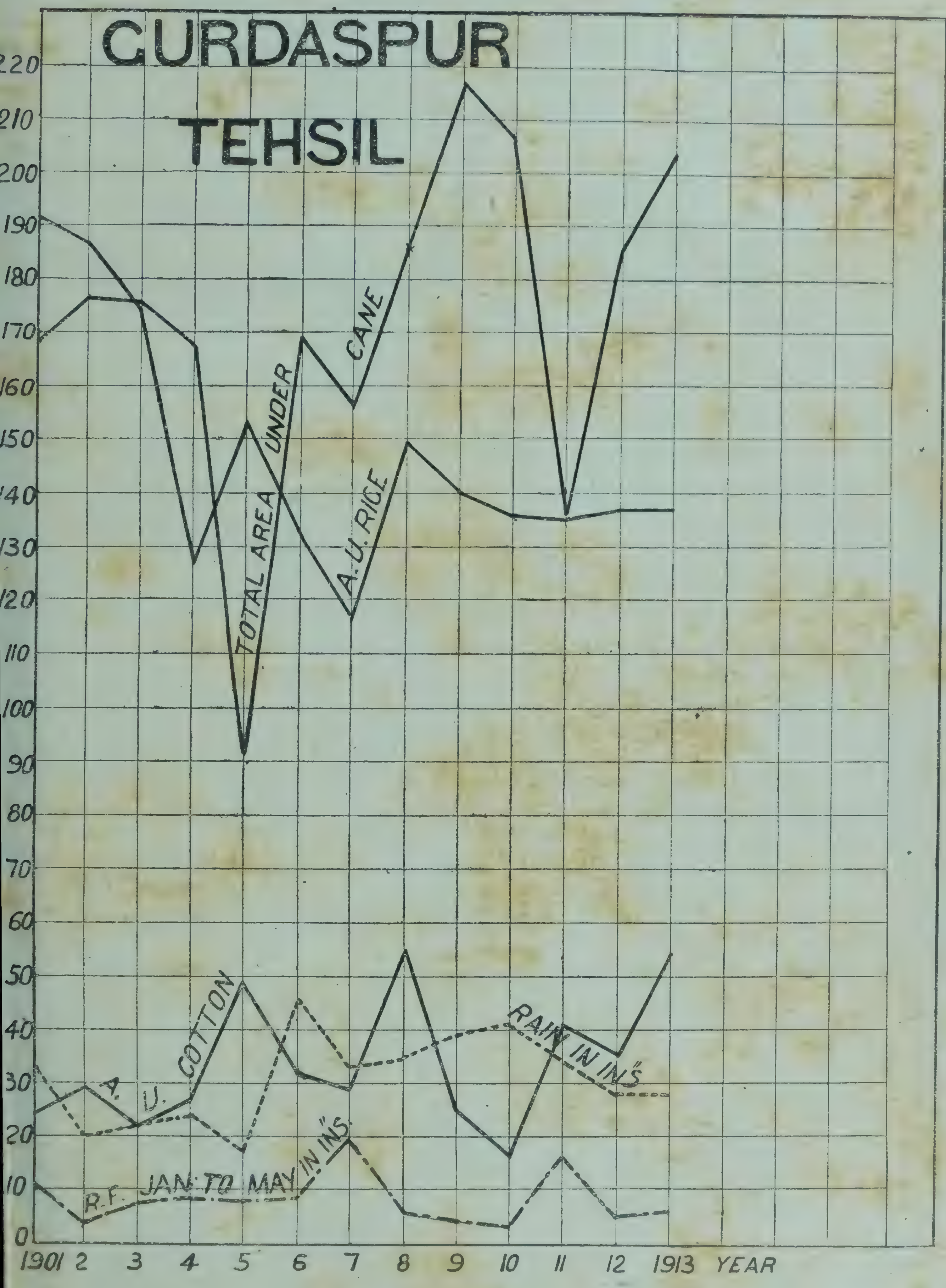
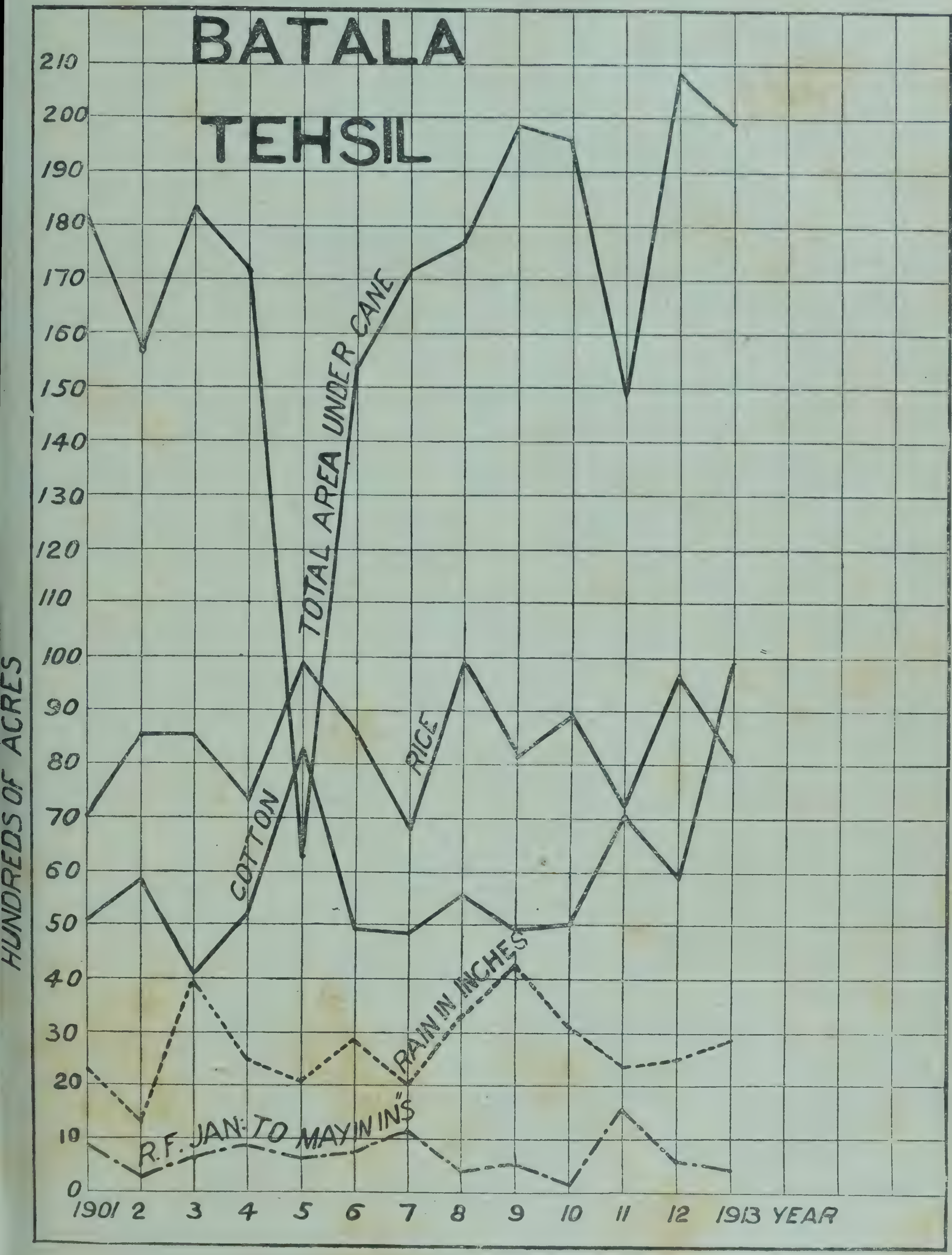
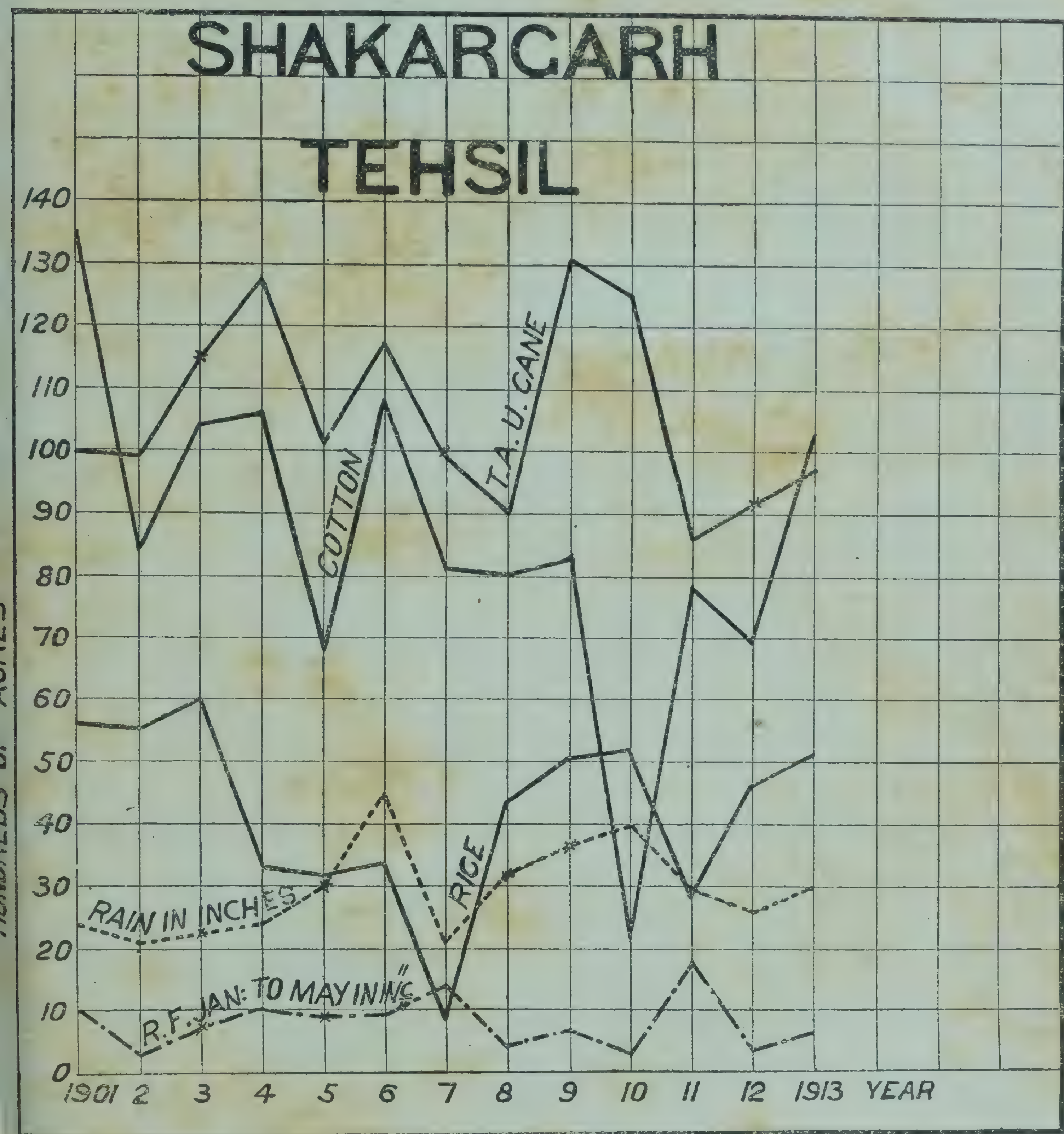

GURDASPUR
TEHSIL
TOTAL AREA UNDER CANE
A.U. RICE
A. U. COTTON
RAIN IN IN'S
R.F. JAN TO MAY IN IN'S
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1901
2
3
4
5
6
7
8
9
10
11
12
1913
YEAR

DIAGRAM VI.



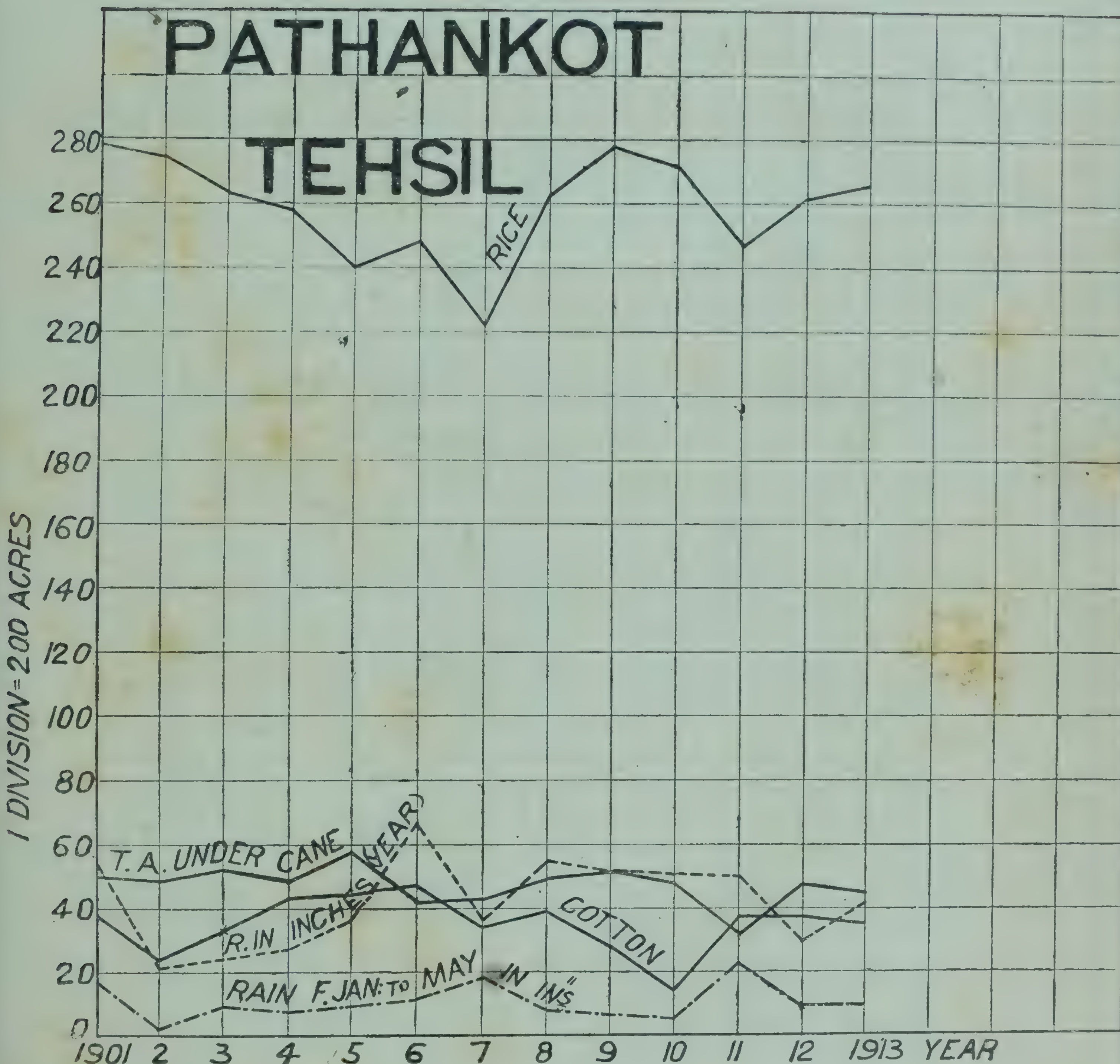
BATALA
TEHSIL
TOTAL AREA UNDER CANE
RICE
COTTON
RAIN IN INCHES
R.F. JAN: TO MAY IN INS"
HUNDREDS OF ACRES
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1901 2 3 4 5 6 7 8 9 10 11 12 1913 YEAR

DIAGRAM VII.



SHAKARGARH
TEHSIL
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1901
2
3
4
5
6
7
8
9
10
11
12
1913
YEAR
T.A.U. CANE
COTTON
RICE
RAIN IN INCHES
R.F. JAN: TO MAY IN INS.

DIAGRAM VIII.



In the graph showing the acreage under the chief crops in Batala, which is the tahsil growing the largest amount of sugar, we see first that the yearly variation in cane, which is the principal crop, is very great. Of the two other main crops, rice and cotton, we should infer from the comparatively uniform acreage under rice that this crop is grown largely for consumption in the district and is therefore only a minor competitor to cane. Cotton on the other hand has shown a more or less steady increase. This cotton is in direct competition with cane and must be reckoned as a crop of major importance.

In the Gurdaspur tahsil where there is also a large amount of cane grown, we see that rice is much more directly in competition while cotton, though on the increase, is still very variable. The Shakargarh tahsil perhaps provides the best example of this competition between crop and crop. Cotton is evidently a crop of major importance in this tahsil and the wide variation in the amount sown shows that the farmer's attention is more on the cotton market than on sugar. The area under cane does not vary to the same extent as in Batala or Gurdaspur.

In the Pathankot tahsil which is the portion of the district nearest to the foot-hills, rice is the principal crop ; all the cane grown is evidently for local consumption. A small amount of cotton is grown, but the area under this crop is comparatively uniform.

In no case does there appear to be any relationship between the amount of any crop sown and the rainfall either annual or of the spring rains. This is interesting and not altogether unexpected. We can only explain it by the assumption that in the tahsils of Batala, Gurdaspur, Shakargarh and Panthankot there is usually sufficient water either from canals, wells or rain to ensure the sowing of the crop. We are not concerned in this enquiry with the yields or what proportion of the crop comes to maturity, that obviously depends on the season, but *the amount sown is the real index of the zemindars' forecast of comparative crop values.* From these figures it appears that in the south and west of the district, cotton is in direct competition with cane and the area under this crop will probably increase. Near the hills, rice is the chief crop by reason of the abundance of water in the hot season, and such cane as is grown, is evidently for local consumption only.

When deciding on the crop to be sown the farmer will naturally be influenced by the value of the produce. But besides this, he has also to consider the outlay in labour, manure and money. This cost varies considerably with the crop and is widely different in different parts of the Province.

Below is given an abstract in tabular form of Hamilton's estimate of the expenses and profits of cultivation in the Punjab,

TABLE LII.

Showing cost of cultivation and profit in growing ordinary crops in the Punjab.

Crop	District	How irrigated	Interest on capital outlay on bullocks and implements	Cost of production	Value of produce	Profit per acre	REMARKS
			Rs. a. p.	*Rs. a. p.*	*Rs. a. p.*	*Rs. a. p.*	
Wheat	Lyallpur (Buchiana)	Canal	10 4 0	35 8 6	73 5 0	37 12 6	Cost of production and value of produce are per acre.
Cotton	Do.	Do.	10 4 0	29 6 6	72 0 0	42 9 6	
Wheat	Amritsar (Tarn Taran) Tahsil	Do.	10 2 0	31 11 0	73 5 0	50 6 0	Cost of production and value of produce are per *ghumaon*.*
Cotton	Do.	Do.	10 2 0	24 1 0	72 0 0	58 0 0	
Wheat	Sharakpur Tahsil	Well	16 0 0	42 8 0	79 0 0	36 8 0	Cost of production and value of produce are per acre.
Do.	Gujranwala Tahsil	Do.	22 3 0	44 7 0	73 11 0	29 4 0	
Sugarcane	Gurdaspur	Canal	13 12 0	54 1 0	96 0 0	50 0 0	Cost of production and value of produce are per *ghumaon*.
Do.	Do.	Do	13 13 0	63 8 0	96 0 0	39 4 0	
Sugarcane, variety *Pounda*	Hansi	Do.	19 11 0	226 13 0	270 0 0	69 0 0	Both the cost of production and value of produce are per *pucca* bigha.

Unfortunately these estimates do not give any account of the cost of growing cotton and the profits derived from it in the Gurdaspur District but an estimate is given for Tarn Taran tahsil in the Amritsar District which is adjacent to Gurdaspur.

The profits of cotton in Tarn Taran compare very favourably with those derived from cane cultivation in Gurdaspur under canal irrigation. Another point in favour of the cotton crop is the smaller outlay in capital and cost of production than is required in the case of cane. This will prove a powerful incentive to cotton growing with the Punjab peasant, who, like the small farmer throughout the world, is never overhanded with spare cash.

It would appear from this paragraph that I am advocating the growth of cotton and rice in lieu of cane in the Gurdaspur District, whereas this bulletin is mainly one about cane. I do not intend this; the point I wish to make clear is that there are other crops in competition with cane, and that there is every likelihood of these displacing cane unless this is very materially improved. I have shown elsewhere that I have good reason to believe that the Gurdaspur climate is not suitable for the growth of an improved variety of cane which can only be regarded, therefore, as a foreign crop. This being so, I venture to forecast that cane cultivation will decline there, and its place will be gradually taken

* A *ghumaon*=0·826 acre.

by other more suitable crops which will ultimately prove to be more remunerative. This becomes more clear when we compare the interest returned in profits from the sale of the produce on the capital invested in growing it. Thus for example, the interest yielded by cotton is over 100 per cent., for wheat just under 100, and for sugarcane from 24 per cent. upwards, the highest being only 86 per cent., and this latter in all probabilities is an abnormal figure.

Yield per acre the ruling agricultural factor in the industry.

The yield of cane obtained in the district has been very fully discussed in Chapter I. We have seen there that the estimated average for the district is somewhat above 10 tons of stripped cane to the acre. Higher yields than this can be, and are, obtained, but in forcing up the outturn the law of diminishing returns will apply as it does in the case of all agricultural products. The yield of ten tons may be a low average, but I am inclined to think that it is about the yield at which the zemindar gets the highest interest on his capital outlay. In other words he has pretty well reached the limit with the implements, manure, soil and water at his disposal and in the climate in which he has to work. Any marked increase over this average must mean more than average favourable conditions in one or other of the above. Otherwise more and more capital will have to be employed in obtaining increased yields.

In Table LII for example, with a capital outlay of Rs. 58 per acre in Gurdaspur, the return was 86 per cent. ; with an outlay of Rs. 77 it was 52 per cent. ; while with an outlay of Rs. 246 on *Pounda* cane the return on the capital invested was only 24 per cent. This is a point of vital importance to the small farmer, and for this reason it is useless and impossible to compare the conditions of the industry in Gurdaspur with that of other cane-growing countries on the yield per acre alone. That the out-turn of cane in Gurdaspur is below that of most other sugar-growing countries is certain, and it is only the isolated position of the district, the heavy freightage rates, and the fact that India is producing less sugar than she consumes, which enables the farmer in Gurdaspur to continue to grow cane on a large scale.

4. Curtailment of the losses taking place in the manufacture of sugar.

The losses which take place in the manufacture of sugar by country methods in the district are very great and there is scope for immediate improvement.

The principal losses take place in (*a*) crushing and (*b*) boiling. The estimates I have given for the losses in crushing in Chapter II are certainly

very much below those normally taking place in the villages. Hulme considers that the extraction effected by the ordinary country mill is about 56 per cent. or in other words not a very great improvement on Lehman's estimates (*loc. cit.*).

Two methods suggest themselves for the curtailment of this loss. The first is its reduction by better machinery, to be owned and run by the farmer, just as he owns or hires the bullock-driven crushing mill to-day. The other method is more complicated—it involves the use of machines of higher power and greater cost than could be managed by any ordinary farmer and would need special management.

The first of these two methods is being tried in the United Provinces by the Agricultural Chemist, and consists of the use of a mill capable of crushing 12 to 15 maunds of cane per hour and driven by an oil engine of from 5 to 7 B. H. P. and costing about Rs. 500.* The mill gives an expression of 55—59 per cent. with *Ukh* canes and 62—66 per cent. with *Pounda* canes. This is better than the village mill as ordinarily used in the United Provinces, but not equal to a Nahan 3-roller mill driven by bullocks. This latter is not however within the means of the ordinary cultivator.

The second method is under trial in the United Provinces by the Sugar Engineer to the Government of India, Mr. Hulme. At Nawabganj a factory costing Rs. 50,000 and capitalized at Rs. 80,000 (Rs. 30,000 being set aside for the pre-payment of the cane) has been erected. This is capable of milling 30 maunds per hour at 22 hours per day for 91 days or about 60,000 maunds of cane in the season. In the opinion of the designer this is the smallest sugar boiling plant that can be economically used. It makes both white sugar as well as ordinary country *gur*. It does not use vacuum evaporating pans but only Wertzel pans.

By the courtesy of the Director of Agriculture, Mr. Hailey, and of Mr. Hulme, I had an opportunity of inspecting this factory in February last. It appears to be a valuable experiment, but all the problems capable of solution by it have not yet been solved. The principal difficulty experienced has been in obtaining a sufficient supply of cane to keep the factory fully employed. This difficulty will always be experienced with any similar factory unless the factory either owns a portion of the adjacent sugar land, sufficient to supply at least ¼ of the season's consumption, or else the farmers growing the cane must have an interest in the factory itself to act as an inducement to them to supply the factory with as much cane and at as low a figure as possible. One cannot lay down any hard and fast rule as to which is the better method, for the system effective in one district or province may not be so in another.

* *Proceedings of the Board of Agriculture in India*, 1916, page 93.

Speaking of the Punjab and the sugar growing conditions which exist there as I have seen them, I believe the latter system of co-operation between grower and sugar boiler is the most promising, and if successful, will not only effect a considerable saving in the terrible waste now taking place but will also set free the farmer's cattle as well as the farmer himself for other work more directly connected with the farm.

At Nawabganj the factory makes 3 grades of white sugar obtaining a molasses by-product. It was estimated to yield 6 per cent. of sugar on the cane crushed at an average price of Rs. 13 per maund and 5 per cent. of molasses at an average value of Rs. 2-8 per maund. These figures have not been realized in the present working season (1916) owing to losses in the factory and the sale of part of the sugar in an unrefined state. The actual return of refined sugar on the cane crushed was only 3·6 per cent.

The efficiency of the mills is 83·3 per cent. on 19 crushing and using different types of cane and the return of *gur* is about 11 per cent. of the weight of cane. The following is the result of 3 days' working at Nawabganj :—

Date	Weight of cane crushed	Weight of juice	Weight of *gur*	Percentage of *gur* on cane
	Mds. Srs.	Mds. Srs.	Mds. Srs.	Per cent.
9th January, 1916 . . .	221 33	151 25	25 12	11·39
10th January, 1916. . .	188 30	127 30	23 26	12·51
7th January, 1916 . . .	171 29	109 5	18 0	10·05
AVERAGE .	..	..	..	11·30

The cost of production is about Rs. 5-4 per maund of *gur* when the cost of cane is R. 0-5-3 per maund, this being the price actually paid for cane at Nawabganj. The price of *gur* varies. According to Noel Paton (*loc. cit.*) the average price of *gur* in 45 districts was :—

	Rs.
1906	5·53 per maund.
1907	5·04 „
1908	5·39 „
1909	5·95 „
1910	5·96 „

In Lyallpur and Gurdaspur districts, the price of *gur* this year (1916) is about Rs. 5 per maund.

The price paid for cane at Nawabganj is high—better cane can be purchased in parts of Bihar at R. 0-4-0 per maund. At Sujanpur in the Pathankot tahsil, there is an old established sugar factory which buys the cane in advance and pays from Rs. 20 to upwards of Rs. 40 per acre, the average out-turn of which is about 200 maunds. Taking Rs. 30 as the average price per acre paid this costs on the field R. 0-2-5 per maund of cane, and at the factory, after paying carting charges at R. 0-0-9 per maund, gives R. 0-3-2 per maund.

On the other hand Dyer's scheme for making *gur* in the Gurdaspur and Amritsar districts at Chinna, Batala, and Amritsar, using steam driven mills, broke down because he could not purchase enough cane to keep the mill working even at R. 0-6-0 per maund.

5. Cost of production of the cane and the price at which it could be supplied to a factory.

Hamilton[1] has estimated the cost of production of cane on canal irrigated lands in the Gurdaspur District at about Rs. 50 per acre (exclusive of charges for sugar boiling). Unfortunately he gives no figure for the rent value of the land, and this somewhat detracts from the value of his figures. At Rs. 50 per acre and with a yield of 300 maunds of cane, this gives the cost of growing the cane at R. 0-2-9 per maund; add carting charges at the rate of 20 maunds per cart for 15 days at R. 1 per day—we get a carting charge of R. 0-0-9 per maund of cane.

The rent of the land is difficult to estimate—this is sometimes taken as half the value of the crop grown—the owner supplying seed and sometimes other things also. It is difficult to deduct a rental value for this system, since cane only occupies a portion of the land ($\frac{1}{3}$rd in the ordinary rotation followed, see Chapter I), less remunerative crops being grown on the other parts at the same time. Moreover, the tenant gets fodder crops in the *kharif* season of which the landlord takes no share. Land is let on a money rental in some places, but the value varies very much. The land commanded by canal irrigation for example is very much more valuable than that which has to be irrigated from wells. I have taken Rs. 15 per acre as an average figure for the rent value of land in Gurdaspur. I am fully aware that there are many farms on which cane is grown which command a higher figure than this, but on the other hand there are many others which can only realize much less, just as is the case with the out-turn of cane per acre. This figure for rent value of the land gives a rental charge of R. 0-0-10 per maund of cane grown (taking 300 maunds as the yield per acre). The

[1] *Expenses and profits of cultivation in the Punjab*, Punjab Government Press, 1916.

total cost of producing the cane and landing it at the factory is estimated as follows :—

	Rs.	A.	P.	
Cost of growing	0	2	9	per maund of cane.
Rent of land	0	0	10	"
Carting	0	0	9	"
TOTAL .	0	4	4	per maund.

Since this is more than the price paid at the Sujanpur factory, we can only conclude that, in the Pathankot tahsil at least, the cost of growing the cane *is much less than the above estimate.* These figures are only approximately correct, and their value lies in the proof they afford that the cultivator can grow and deliver his cane at a central crushing and boiling mill at a price which will yield a margin of profit both to him and to the mill-owner.

Factories of the type at Nawabganj offer a partial solution of the problem of present waste. I do not think that a factory of this type will be able to stand competition from a large refinery but it will take some years before such refineries can come into existence in sufficient number to seriously affect the price of sugar in India, and in Northern India particularly the day is far distant when sugar factories will be seen. In the meantime any system, which is an improvement on that at present in vogue, will be of assistance in increasing the out-turn of raw sugar and rendering the country more independent of the imported products. We have only to turn to the reputed losses shown in Chapter III, to see what a large margin there is for improvement in this direction—probably a larger margin than there is for the improvement of the cane itself in Northern India.

The estimates I have given in Chapter III are certainly less than is actually the case in the villages, for the milling and boiling on which these estimates of losses are based, is far better than in the villages. I shall not deal here in detail with improvements which can be effected in the boiling of the juice, as it will make this account of the Gurdaspur sugar industry too bulky and would serve no useful purpose. Improvement can only be effected by the use of better machinery and by skilled labour, both of which are beyond the reach of the present farmer unless the above system of co-operation can be secured. The type of machinery which would be used, may be seen by reference to an account of the Nawabganj[1] factory.

[1] "A note on the improvement of the indigenous methods of sugar and *gur* making in the United Provinces, being a report of the Government experimental sugar factory at Nawabganj" by Mr. Hulme. Allahabad Government Press, 1916.

From the table No. XLI on page 71, Chapter IV, it will be seen that the excess of imports over exports in the *gur* trade of the district was 49,23,181 maunds in 1911-12. The area under cane in the district is about 50,000 acres with an average out-turn of about 24 maunds of *gur* to the acre. In order to check this importation of *gur*, therefore, it will be necessary to either quadruple the area under cane or raise the yield per acre to four times its present value if the internal consumption of sugar is to be met locally. We cannot materially increase the area under cane, for this would disturb existing agricultural conditions, nor is there any likelihood of increasing the yield per acre to anything like this figure. There is, however, some room for improvement in the manufacture of *gur* itself, in checking losses in crushing and boiling and, while there is so much cane grown in the district, an effort should be made to minimize these losses. This will be a real improvement and a boon not only to the Gurdaspur farmer but to the sugar consumer throughout India.

The Composition of some Indian Feeding Stuffs.

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Introduction.

Mr. Mackenna in his book on "Agriculture in India" observes, at page 97, that the prosperity of Indian agriculture depends greatly on the maintenance in health of the cattle of the country. The maintenance of cattle in a healthy state, in its turn, depends largely on the supply of proper food—a problem of no small importance. The poorer cultivators have so long been depending mainly on grass supplemented by straw and odds and ends from their farm produce. Circumstances are, however, changing and at least some of them have now got to buy commercial feeding stuffs. The problem is of great importance to the dairyman too, whose aim is to get the best possible return for the money laid out in feeding his stock.

How to feed cattle in the proper way cannot be learnt from books alone. A knowledge of the composition of feeding stuffs coupled with practical knowledge of stock-keeping, however, leads a long way towards a judicious blending of the foods and thereby obtaining a well-balanced and economical ration.

The functions of a feeding stuff.

Food is necessary to an animal—

1. To maintain the temperature of the body. The nutritive constituents of a food are oxidized in the body and thus produce heat which serves to keep the animal warm.
2. To provide energy for doing internal work. Even when an animal is not doing any external work, there is involuntarily going on work inside its body to carry out the different physiological functions incidental to vital activities.
3. To replace wear and tear in the body. As a result of the vital processes going on in the body of an animal effete chemical products are constantly being removed from

the system. Fresh materials must be given to the animal to replace this waste.

4. To produce new growth. This holds specially in the case of young animals which have not reached their limit of growth. Milch cattle must also be provided with nutrients from which they can synthesize the constituents of milk. In the case of other adult animals, while they cannot put on flesh beyond a certain limit, they can increase the store of their fat.
5. To produce the energy required for performing external work, as in the case of work cattle.

The constituents of a feeding stuff.

The usual chemical analysis of a feeding stuff consists in the determination of the contents of moisture, crude fat, albuminoids, soluble carbohydrates, woody fibre and ash. Short explanations are given below of these constituents and of the parts they play in animal economy.

Moisture. All feeding stuffs contain considerable proportions of water, even when apparently dry. The amount varies with the condition of the weather and the nature of the food.

Water is no doubt of great physiological importance in the economy of animal life but since it is furnished for the most part in liquid form, the moisture in feeding stuffs cannot be considered as having any special nutritive value. Other things being equal, moist foods should be correspondingly low in price. Besides this, the presence of too much moisture in a feeding stuff makes it liable to " heat " and to be spoilt by moulds, etc.

Ether extract or crude fat. The so-called " oil " or " fat " is generally estimated by treating the feeding stuff with ether. The extract is composed mainly of fats and oils in the case of concentrated feeding stuffs, but with fodders and hays, ether dissolves also other substances (*e.g.*, waxes, colouring matter, organic acids, etc.)

The injested fat is oxidized in the body to produce heat and energy and, when there is a sufficiency, acts as a source of animal fat. Ordinarily this latter is stored in the body but is excreted in large quantities by milch cattle in the milk they yield.

Albuminoids or crude proteins refer to a group of substances which contain nitrogen as one of the essential elements. These are estimated from the percentage of nitrogen, which is multiplied by the factor 6·25 to give the content of albuminoids. For this purpose the

"albuminoid" nitrogen content is to be taken into account but the calculation is based sometimes on the total nitrogen figure.

It is thus seen that albuminoids are supposed always to contain 16 per cent. nitrogen, an assumption which is not quite correct. The nitrogen which is present in a feeding stuff is moreover not present wholly as pure protein. The younger and tenderer parts of a plant, germinated seeds, roots, berries, juicy fruits as well as feeding stuffs which have undergone acid fermentation or have been acted upon by yeasts and bacteria, contain appreciable amounts of non-protein nitrogenous substances.

No animal can live unless it gets a certain amount of protein which is indispensably necessary to repair the nitrogenous waste in the tissues. Growing animals and milch cattle must also be supplied with protein over and above that required for repairing the tissues. This holds to a lesser extent in the case of animals which yield wool. Fully grown animals lack the power of increasing their store of protein or flesh beyond a certain limit and the excess of protein supplied to them with their food gets oxidized in their body or is utilized in maintaining the body heat and supplying energy, a part being also utilized for the formation of body fat.

Many non-protein nitrogenous substances have a much smaller food value than proteins. They serve as fuel and can save waste of the proteins. Ruminants, however, can to a certain extent utilize nitrogenous substances of a non-protein character towards forming flesh, the change being brought about by the help of bacteria in the partly digested food.

Soluble carbohydrates. In the analysis of foods all matters not included in moisture, crude fat, albuminoids, woody fibre, and ash are classed as soluble carbohydrates. These are therefore composed of a number of different substances. Their function is in the main the same as that of fat, although they are less efficient than the latter.

Woody fibre. The cell walls and woody fibres of a plant are entered under this head. It is mostly indigestible and the fraction which is digestible requires the spending of a relatively large amount of energy to assimilate it. In the presence of much woody fibre in the food, animals can utilize the nutrients only to a smaller extent. Though of not much direct value as a food to the animal, a certain amount of woody fibre is however required in the food to give it bulk and thus to have the stomach properly filled. Feeding materials of low value, such as straw, hulls, etc., contain a high percentage of woody fibre and their addition to a concentrated feeding stuff adds to the amount of woody fibre in the latter. The determination of the amount of woody

fibre thus often serves to detect adulteration of concentrated feeding stuffs.

Ash consists of the mineral constituents of the feeding stuffs. A part of the ash is soluble in acids, and the rest consisting mainly of sand is insoluble. An excessive amount of sand in a feeding stuff indicates contamination with dust, etc.

For the growth of bones animals require lime and phosphoric acid. The blood contains iron and other mineral substances. Again, phosphorus and sulphur are essential constituents of the animal cell. Hence the food of an animal must contain a certain amount of these inorganic constituents to keep the animals in good condition. In some cases it may even be necessary to specially provide for mineral food in the shape of cattle licks containing specific salts.

It is thus seen that the constituents of a feeding stuff which practically determine its value for purposes of animal nutrition are the fats, the proteids and the soluble carbohydrates.

The digestibility of feeding stuffs.

Only that part of the food is of direct value which the animal assimilates. Digestibility experiments have been carried out in Europe and America, but unfortunately none has yet been done in India.

Feeding stuffs can be divided into two classes :—(1) concentrated foods, which include cakes and grains, and (2) roughages in which may be included grass, straw and hay. The concentrates are poor in woody fibre and the nutrients contained in the food are of a high degree of digestibility. On the other hand, the roughages are rich in woody fibre and the nutrients contained in the food have a low digestive coefficient. A comparison of the feeding values of substances of the *same* class of feeding stuffs, on the assumption that similar constituents are equally assimilable, is not likely to lead to any serious error. A concentrated feeding stuff cannot, however, be compared with a coarse fodder merely from figures about their chemical analyses.

Albuminoid ratio.

As already pointed out, for the purposes of generating heat and energy and for production of fat, animals can utilize either albumi-

noids, fats or carbohydrates. But for the production or repair of the tissues, etc., of its body the animal must have some albuminoids in its food. Fats or carbohydrates cannot discharge this function.

Fat is a relatively concentrated nutrient as will be evident from the fact that one pound of fat gives, on oxidation, about 2·3 times as much heat as is given by a pound of albuminoids or of carbohydrates. Hence, the percentage of fat in a feeding stuff should be multiplied by the factor 2·3 to indicate the efficiency of the content of fat as measured by the same standard as is applicable to the albuminoids and the carbohydrates.

The ratio of albuminoids to the soluble carbohydrates and fat (as calculated to its carbohydrate equivalent) is known as the albuminoid ratio. For instance, if a sample of feeding stuff contains 4·2 per cent. fat, 17·0 per cent. albuminoids, and 60·0 per cent. soluble carbohydrates, the albuminoid ratio may be calculated thus :—

Fat = $4{\cdot}0 \times 2{\cdot}3$	= 9·2	equivalents
Soluble carbohydrates	= 60·0	,,
Sum .	= 69·2	,,

$$\text{Therefore albuminoid ratio} \quad . \quad . \quad . \quad . \quad = \frac{17{\cdot}0}{69{\cdot}2} = 1 : 4{\cdot}1$$

If the proportion of albuminoids in the food falls below the proper limits, the animal will not get the necessary amount of nitrogenous material to repair the waste going on within its body and consequently the growth of the body will be restricted. On the other hand, when the food contains more albuminoids than are required, the extra amount of albuminoids, which are more costly than the other ingredients, will in the animal's body merely perform the functions which can more cheaply be performed by fats and carbohydrates, and simultaneously there will be a larger excretion of nitrogenous matter. It is thus seen that the proportion of albuminoids in the food of cattle is fixed by considerations of the health of the animals and of the higher cost of albuminoids for heat production as compared with fats and carbohydrates. From the practical point it is therefore advisable to supply just a little more than the required amount of albuminoids.

Feeding standards.

The following albuminoid ratio has been found to be the most suitable for different kinds of stock :—

Albuminoid ratio.

Oxen at rest	1 : 12
Oxen at work	1 : 7
Fattening cattle	1 : 6
Milch cows	1 : 6
Dry cows	1 : 7
Sheep (wool)	1 : 9
Breeding ewes (with lamb)	1 : 6
Fattening sheep	1 : 5
Horses at work	1 : 6
Brood sows	1 : 7
Fattening swine	1 : 6
Growing animals, very young	1 : 4
Growing animals, half-grown	1 : 6

The figures quoted above have been found out by feeding experiments and practical experience, and represent what in general, and under average conditions, constitute suitable rations for the particular purposes in view. They need not, however, be accepted as absolute standards and may be varied according to circumstances. For instance, it may after all be economically better, under a given set of conditions, to deviate to a certain extent from the standard. And in particular cases the figure quoted above may not exactly suit the requirements of an individual animal. The palatability of a ration is a very important factor. But the taste and general specific characters of foodstuffs for particular animals can only be found out by experience. In general animals flourish better on a ration which they like, even if it does not correspond to the standard, than on one which, although scientifically made up, they do not like, and the feeder has to study the individual whims of the animal.

Nevertheless the figures given above have an importance as a matter of guidance, and it may be laid down that in general the object of the feeder should be to secure a mixture of feeds in which the proportion of albuminoids in the total rations must not be below one-seventh or exceed one-fifth part of the soluble carbohydrates and fat (calculated as its carbohydrate equivalent).

Besides a proper nutritive ratio in the feed, its bulkiness must be taken into consideration. If the food is too bulky the animal cannot eat enough of it to get proper nutrition. On the other hand if the food is not bulky enough, the digestive organs of the animal will not be sufficiently distended to permit the maximum possible assimilation.

Computing rations.

It is a simple matter to calculate what the albuminoid ratio in a given mixed feed is. As an example the following ration may be taken :—

Green juar	20 lb.
Wheat straw	20 ,,
Rahar chuni	3 ,,
Wheat bran	2 ,,

An examination of the tables at the end of this book shows the average composition of the above feeding stuffs to be :—

	Crude fat per cent.	Albuminoids per cent.	Soluble Carbohydrates per cent.
Green juar	0·5	1·2	9·0
Wheat straw	1·3	3·2	38·0
Rahar chuni	1·5	18·0	50·0
Wheat bran	3·5	12·0	60·0

The nutrients contained in the mixed feed are therefore :—

	Fat lb.	Albuminoids lb.	Soluble Carbohydrates lb.
In 20 lb. green juar . .	0·10	0·24	1·80
In 20 ,, wheat straw . .	0·26	0·64	7·60
In 3 ,, rahar chuni . .	0·05	0·54	1·50
In 2 ,, wheat bran . .	0·07	0·24	1·20
TOTAL .	0·48	1·66	12·10

Hence the albuminoid ratio is $1{\cdot}66 : \{(0{\cdot}48 \times 2{\cdot}3) + 12{\cdot}10\}$ or $1 : 8{\cdot}0$.

The ration is thus seen to be rather poor in albuminoids. In order to make good this deficiency the addition of a food rich in albuminoids should be made. If one pound of wheat bran is substituted by one pound of groundnut cake (containing about 10 per cent. fat, 40 per cent. albuminoids and 25 per cent. soluble carbohydrates) the composition of the feed will be :—

	Fat lb.	Albuminoids lb.	Soluble Carbohydrates lb.
In 20 lb. green juar . .	0·10	0·24	1·80
In 20 ,, wheat straw . .	0·26	0·64	7·60
In 3 ,, rahar chuni . .	0·05	0·54	1·50
In 1 ,, wheat bran . .	0·04	0·12	0·60
In 1 ,, groundnut cake .	0·10	0·40	0·25
TOTAL .	0·55	1·94	11·75

Therefore the albuminoid ratio in this feed is :—

$$1{\cdot}94 : \{(0{\cdot}55 \times 2{\cdot}3) + 11{\cdot}75\}$$
$$\text{or } 1 : 6{\cdot}7$$

The ration now corresponds as closely to the standard ration as can be reasonably expected in practice.

Food units.

It is very desirable to ascertain the feeding values of different feeding stuffs on an uniform basis. The difficulty is, however, in the choice of a proper standard.

As has been noted before, the valuable constituents of a feeding stuff are the fat, albuminoids, and soluble carbohydrates. Fat is more costly to buy than soluble carbohydrates. Moreover, it is about 2·3 times as efficient as carbohydrates considered as sources of energy and heat. Albuminoids, although about equal in fuel value to soluble carbohydrates, are in other respects valuable in as much as they alone are capable of repairing nitrogenous waste going on in the body of an animal. Moreover, the products voided by an animal getting an excess of albuminoids in its food is of direct manurial value. Apart from these considerations, albuminoids are more costly to buy. For all these reasons it may be assumed that fats and albuminoids are about equal in value and are two and a half times as valuable as soluble carbohydrates. There is a general agreement between the market values of the concentrated feeding stuffs and the figures obtained on the basis of these calculations.

In such a system no account is taken of the digestibility co-efficients of the feeding stuffs in question. Moreover, it is assumed that woody fibre has no feeding value and that the constituents of the same class (*e.g.*, fats), though derived from different sources, have the same feeding value.

This method of valuation though not scientifically accurate will probably be useful to the practical man and will help him to find out which, of a number of foods, is *relatively* the cheapest.

Tables of analyses.

Below are given the results of analyses of various feeding stuffs which have been made in the laboratory of the Imperial Agricultural Chemist.

It may be noted here that the albuminoids have been calculated by multiplying the albuminoid nitrogen figure by the factor 6·25. In some cases, however, only the total nitrogen was estimated and the albuminoids calculated from this. These figures are marked with an asterisk in the tables. The samples, the analyses of which have been published in the *Agricultural Ledgers* No. 10 of 1901 and No. 7 of 1903, are marked with the letter " L."

ACACIA ARABICA, *Willd.*

English.—Indian Gum Arabic.

Vernacular.—Babúl, Kikar.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Crushed	*seed*						
14/1915	Crushed Kikar seed, Karnal	10·80	2·91	11·86	54·60	13·20	5·11	1·52	2·09	1·90	5·17	91·5

ARACHIS HYPOGÆA, *Linn.*

English.—Groundnut, Earthnut, Peanut.

Vernacular.—Mungphali, China-badam, Vilayeti-mung, Bhui-mung.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Kernel							
58/1893 L	Groundnut kernel .	4·60	49·25	29·09*	13·21	1·65	2·15	0·05	4·65	..	4·35	209·1
48/1913	Groundnut seed from Kilgiri	5·08	46·48	32·25	12·85	1·15	2·16	0·03	5·16	5·16	3·71	209·7
49/1913	Groundnut grown at Bhagoda, Desur	4·62	50·10	29·09	13·25	1·21	1·66	0·07	4·79	4·65	4·42	211·2
50/1913	Groundnut grown at Khanapur	4·51	50·72	27·03	14·38	1·29	2·01	0·06	4·50	4·33	4·85	208·8
					Shell							
57/1893 L	Groundnut shell .	7·35	2·80	7·57*	13·73	55·35	9·45	3·75	1·21	..	2·66	39·7
					Cake							
18/1902	Cake, Satara .	5·42	9·87	32·13	24·98	22·08	4·23	1·29	5·31	5·14	1·48	130·0
281/1914	Do. Kirkee .	7·47	11·78	43·91	27·65	3·04	4·40	1·75	7·33	7·03	1·25	166·7

AVENA SATIVA, *Linn.*

English.—Oats.

Vernacular.—Jai.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain							
173/1893 L	Cape oats, Cawnpore	10·80	5·93	8·77*	57·95	12·50	1·25	2·80	1·40	..	8·16	94·7
6/1898 L	Oats, Dehra Dun .	10·17	5·27	6·39	61·57	11·29	1·89	3·42	1·18	1·02	11·53	90·7
427/1900 L	Cape oats, Cawnpore	10·43	5·86	7·87	58·62	13·20	1·44	2·58	1·37	1·26	9·16	92·9
277/1914	Oats, Kirkee .	5·99	5·87	8·64	62·34	12·11	1·85	3·20	1·51	1·38	8·79	98·6
					Kernel							
592/1907	Oats, Motipur .	10·06	8·71	15·15*	62·37	1·88	1·67	0·16	2·44	..	5·44	122·0
593/1907	Do. Birauli . .	9·84	9·47	20·44*	57·04	1·84	1·37	0·00	3·27	..	3·86	131·8
594/1907	Do. Pusa . .	9·25	8·57	18·81*	59·66	1·91	1·77	0·03	3·01	..	4·22	128·1
					Husk							
595/1907	Oat husk, Motipur	11·22	0·89	2·49*	44·31	35·80	0·97	4·32	0·40	..	18·62	5-·8
596/1907	Do. Birauli .	11·43	0·89	2·65*	42·16	37·30	0·76	4·81	0·42	..	16·68	51·0
597/1907	Do. Pusa .	11·46	0·75	2·62*	43·57	35·70	1·04	4·86	0·42	..	17·30	52·0
					Straw							
203/1894 L	Oat straw, Cawnpore	9·53	..	1·37	43·48	36·09	3·72	5·81	..	0·22	31·74	46·9
447/1900 L	Cape oat straw, Cawnpore	9·88	1·97	3·00	41·31	30·13	6·45	7·26	0·53	0·48	15·28	53·7
					Green fodder							
230/1900 L	Green oats, Punjab	83·51	0·37	0·94	9·00	3·99	1·47	0·72	0·19	0·15	10·48	12·3
	Do. do. (dried)	10·00	2·02	5·13	49·14	21·78	8·00	3·93	1·04	0·82	10·48	67·0
4/1916	Green oats (dried) .	4·75	1·94	6·25	45·69	30·19	7·23	3·95	1·30	1·00	8·02	66·2
107/1916	Do. do. .	3·36	1·94	4·97	45·47	32·19	10·73	1·34	2·22	0·80	10·05	62·7

BASSIA LATIFOLIA, *Roxb.*

Vernacular—Mohua, Illupei.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Cake							
593/1902	Mohua cake . .	21·48	9·06	14·19	42·56	4·20	4·25	4·26	2·40	2·27	4·47	100·7
593 A/1902	Do., Sambalpur	15·75	19·30	13·68	40·23	4·96	4·04	2·04	2·25	2·19	6·19	122·7

BRASSICA CAMPESTRIS, *Linn.*

English.—Indian colza.

Vernacular.—Sarson.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain							
186/893 L	Yellow Sarson, Cawnpore	6·15	41·37	23·61*	22·25	2·97	3·40	0·25	3·76	..	4·97	184·7
187/1893 L	Black Sarson, Cawnpore.	7·15	33·87	25·89*	22·04	6·40	4·30	0·35	4·14	..	3·86	171·4
193/1893 L	Rai, Cawnpore .	7·50	28·90	16·29*	31·87	5·43	6·16	3·85	2·61	..	6·04	144·8
383/1900 L	Piarka Tori, Dumraon, Bengal.	7·18	41·51	22·25	20·30	4·44	3·90	0·42	3·87	3·56	5·20	179·7
384/1900 L	Lalka Tori, Dumraon, Bengal.	7·10	39·73	19·94	20·91	8·16	4·07	0·09	3·36	3·19	5·63	170·1
386/1900 L	Piarki Tori, Dumraon, Bengal.	7·95	41·42	20·88	22·31	3·32	3·67	0·45	3·50	3·34	5·63	178·1
389/1900 L	Sita Sarisa, Rangpur	7·14	42·62	18·63	23·52	3·43	4·02	0·64	3·26	2·97	6·52	176·6
521/1900 L	Sarson, Arrah .	6·71	43·92	18·75	23·17	2·99	4·12	0·34	3·34	3·00	6·62	179·8
					Green fodder							
232/1900 L	Green Sarson, Punjab	86·13	0·47	2·00	4·64	3·14	2·51	1·11	0·41	0·32	2·86	10·8
	Green Sarson (dried)	10·00	3·05	13·00	30·16	20·41	16·31	7·07	2·66	2·08	2·86	70·3

BRASSICA JUNCEA, *H., f., & T.*

English.—Indian mustard.

Vernacular.—Asl rai, Rai.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain							
380/1900 L	"Kajli Sarso," Bengal.	7·61	40·22	18·44	22·79	5·50	4·01	1·43	3·11	2·95	6·25	169·4
385/1900 L	Lalki tori, Dumraon	8·48	39·46	18·19	24·07	5·75	3·87	0·18	3·18	2·91	6·31	168·2
518/1900 L	Rai, Nadia . .	7·68	32·51	21·94	26·07	5·56	4·89	1·35	3·84	3·51	4·60	162·2
520/1900 L	Rai, Arraria . .	6·95	40·84	18·00	23·47	5·12	4·34	1·28	3·10	2·88	6·52	170·6
318/1903	Mustard, Cawnpore	8·35	41·84	18·57	22·29	4·25	4·32	0·38	3·23	2·97	6·38	173·3
					Straw							
319/1903	Mustard straw, Cawnpore	13·50	1·64	1·94	41·10	32·79	8·24	0·79	0·36	0·31	23·13	50·1
					Cake							
261/1902	Mustard cake, Saugor	6·33	12·59	30·00	33·46	8·84	7·68	1·10	5·24	4·80	2·08	139·9
944/1902	Mustard cake .	8·33	10·91	34·12*	33·36	5·34	7·06	0·88	5·46	..	1·71	145·9
2/1911	Ditto. Military Farm, Agra	6·29	8·47	34·43	37·85	6·84	5·45	0·67	6·14	5·51	1·67	145·1
44/1912	Ditto. .	9·05	8·60	32·88	36·78	5·04	5·68	1·97	6·02	5·26	1·72	140·5
3/1915	Country mill-pressed yellow mustard cake, Cawnpore	10·04	12·17	31·18	36·33	2·89	6·35	1·04	5·60	4·99	2·38	144·7
					Green fodder							
13/1916	Mustard green .	5·94	7·49	8·27	41·58	26·82	8·16	1·74	1·84	1·32	7·11	81·0
108/1916	Do. (Lahi) .	3·27	5·84	6·42	37·74	40·10	6·16	0·47	1·20	1·03	7·97	68·4

BRASSICA NAPUS, *Linn.*

English.—Indian rape.

Vernacular.—Tori, Lutni, Maghi.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain							
388/1900 L	Lutni, Hazaribagh .	7·38	38·21	19·06	23·21	5·06	4·14	2·94	3·29	3·05	5·83	166·4
496/1900 L	Do. Ranchi .	6·48	40·00	17·50	21·54	5·35	4·18	4·95	3·04	2·80	6·49	165·8
519/1900 L	Do. Jahanabad .	6·21	40·18	18·32	24·80	5·30	4·56	0·63	3·18	2·93	6·40	171·1
					Cake							
88/1902	Toria cake, Punjab	6·81	10·28	27·19	37·08	9·85	7·10	1·69	4·66	4·35	2·23	130·8
91/1902	Do. do. .	7·40	11·34	27·88	36·42	8·32	6·44	2·20	4·75	4·46	2·24	134·5
491/1902	Rape cake, Nagpur	24·98	4·83	30·31*	24·16	7·60	6·53	1·59	4·85	..	1·46	112·0
491 A/1902	Do. Cawnpore	20·26	8·79	27·37	27·63	6·35	8·01	1·59	4·78	4·38	1·75	108·0
943/1902	Do. Nagpur .	8·24	8·91	38·37*	31·91	5·80	5·99	0·78	6·14	..	1·37	150·1
959/1902	Do. Bengal .	10·55	12·35	30·25	32·07	7·35	6·14	1·29	5·16	4·84	2·00	138·6
2/1915	Do. Ferozepore	8·28	5·89	34·31	37·93	6·15	5·23	2·21	6·02	5·49	1·50	138·4
5/1915	Do. Agra .	8·28	12·09	29·09	37·43	4·86	6·32	1·93	1·16	1·03	2·24	140·4
317/1915	Do. Dairy Farm, Ambala	8·65	12·31	25·83	39·34	5·69	6·65	1·53	4·79	4·13	2·62	134·5

CAJANUS INDICUS, *Spreng.*

English.—Pigeon pea.

Vernacular.—Arhar, Rahar, Tur.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain							
79/1899 L	Red, Poona . .	8·08	1·32	19·38	61·39	5·94	3·80	0·09	3·35	3·10	3·32	113
90/1899 L	White, Poona. .	7·92	1·23	18·69	62·64	5·99	3·44	0·09	3·44	2·99	3·50	112
271/1899 L	Do. Poona .	8·64	1·91	19·19	60·58	5·24	3·86	0·58	3·41	3·07	3·39	113
203/1900 L	Dark red, Kandulo, Madras.	14·33	1·31	17·25	56·95	6·55	3·56	0·05	3·25	2·76	3·48	103
418/1900 L	White, Cawnpore .	10·89	1·46	14·25	63·68	6·22	3·45	0·05	2·74	2·28	4·70	102
419/1900 L	Red, Cawnpore .	10·94	1·03	16·62	62·92	4·76	3·68	0·05	2·88	·66	3·93	107
833/1902	Tur, split pulse, Poona	13·88	1·72	18·19	61·91	0·83	3·47	0·00	3·70	2·91	3·62	106
302/903	Arhar, Cawnpore .	14·29	1·98	15·82	57·20	5·82	4·40	0·49	3·13	2·53	3·90	101
					Husk							
831/1902	Tur husk, Poona .	13·98	0·73	6·31	47·16	28·93	2·80	0·09	1·02	1·01	7·74	64
8/1911	Karai, Military Farm, Agra	8·27	2·07	5·92	43·83	35·64	3·89	0·38	1·01	0·95	8·21	63
45/1912	Ditto. . .	9·27	0·71	6·47	40·60	36·96	4·21	1·78	1·52	1·04	6·53	58
					Bhusa							
205/1894 L	Cawnpore . .	5·58	..	7·39	45·74	25·69	6·23	8·37	..	1·18	6·19	64
54/1899 L	White, Poona .	6·77	6·93	13·25	45·38	18·10	6·44	3·13	2·45	2·12	4·63	95
55/1899 L	Red, Poona . .	6·22	7·94	14·94	46·51	14·35	6·12	3·92	2·60	2·39	4·33	103
266/1899 L	Poona .	8·89	2·97	7·38	49·94	21·74	6·46	2·62	1·42	1·18	7·69	75
204/1900 L	Rajahmundry, Madras	11·97	1·39	9·19	40·43	20·89	4·59	11·54	1·61	1·47	4·75	66
446/190 L	Cawnpore . .	10·23	2·78	10·31	41·08	21·06	6·92	7·60	1·85	1·65	4·60	73

CAJANUS INDICUS, *Spreng.*—concld.

English.—Pigeon pea.

Vernacular.—Arhar, Rahar, Tur.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
379/1902	Arhar Bhusa .	14·41	2·41	10·81	33·88	21·53	10·80	6·16	2·07	1·73	3·65	66·9
408/1902	Do.	9·69	3·51	9·94	41·81	21·19	6·59	7·27	1·74	1·59	5·02	75·4
303/1903	Do. Cawnpore .	8·28	4·58	9·69	40·87	19·46	6·81	10·31	1·61	1·55	5·30	76·6
303/1914	Do. Bangalore .	7·74	0·32	3·97	45·12	39·16	3·34	0·35	0·65	0·63	11·55	55·8
321/1914	Do. Jubbulpore	9·03	0·29	4·30	43·10	39·30	3·68	0·39	0·74	0·69	10·18	54·6
321/1915	Do. Lucknow .	6·53	1·03	9·51	46·49	30·68	4·53	1·23	1·84	1·52	5·14	72·9
322/1915	Do. Allahabad .	7·74	1·10	7·95	45·53	30·94	4·85	1·89	1·43	1·27	6·05	68·1
					Chuni							
			(Outer integrement of the seed with part of the adhering kernel)									
832/1902	Poona . . .	14·99	2·06	22·25	49·30	7·15	3·98	0·29	3·72	3·56	2·43	110·0
4/1911	Military Farm, Agra	8·67	2·33	15·93	49·63	17·41	4·24	1·79	2·68	2·55	3·45	95·3
61/1911	Do. Muttra	8·44	1·35	15·67	48·19	16·93	4·67	4·75	2·82	2·51	3·27	90·7
275/1914	Kirkee . . .	9·77	0·96	18·25	59·17	3·95	6·21	2·69	3·26	2·92	3·36	107·2

CAMELLIA THEA.

English.—Tea seed.

Vernacular.—Chah.

						Cake						
03/07	Tea seed cake, Kangra	8·12	15·64	10·56	54·46	7·03	3·84	0·35	1·92	1·69	8·56	120·0

CARTHAMUS TINCTORIUS, *Linn.*

English.—Safflower.

Vernacular.—Kasumba, Kusum, Kardi, Kar.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain							
95/1895 L	Safflower, Poona	7·49	31·84	13·31*	18·66	26·31	2·39		2·13	..	6·90	131
92/1899 L	Do. Do.	6·04	18·28	20·44	27·51	23·60	3·78	0·35	3·77	3·27	3·45	124
437/1900 L	Do. Cawnpore	6·23	29·33	11·37	22·97	28·08	0·68	1·34	1·87	1·82	7·95	124
					Cake							
16/1898 L	Safflower cake, Poona	12·00	3·78	16·91	41·48	19·40	4·36	2·07	4·92	2·70	2·97	9[illegible]
16/1902	Safflower cake, Poona	7·55	7·54	42·63	26·19	9·03	5·28	1·78	7·44	6·82	1·02	151
19/1902	Safflower cake, Satara	9·23	10·30	43·19	22·81	8·98	4·59	0·90	7·40	6·91	1·08	150
60/1902	Safflower cake, Chalisgaon	18·53	6·72	36·44	18·06	11·56	5·59	3·10	5·94	5·83	0·92	126
188/1902	Safflower cake, Baroda	7·68	6·98	40·00	26·76	10·90	6·53	1·15	6·80	6·40	1·07	144
189/1902	Safflower cake, Baroda (decorticated)	6·83	6·72	42·13	34·51	3·53	5·43	0·85	7·68	6·74	1·19	156
303/1902	Safflower cake, Dharwar	10·87	6·92	22·25	30·40	25·07	2·96	1·53	3·61	3·58	2·08	10[illegible]
304/1902	Safflower cake, Hubli	11·10	6·06	27·43	26·97	24·76	2·99	0·69	4·45	4·39	1·50	109
685/1906	Safflower cake, Poona	14·22	7·04	47·77	20·19	5·27	4·89	0·62	8·08	7·64	0·76	157
686/1906	Safflower cake, Poona	10·15	8·53	30·06	24·54	20·29	4·12	2·31	5·22	4·81	1·47	121
278/1914	Safflower cake, Kirkee	6·92	13·45	34·73	28·26	11·39	4·39	0·86	5·91	5·56	1·71	148

CICER ARIETINUM, *Linn.*

English.—Common or Bengal gram, Chick-pea.

Vernacular:—Chana, Chhola, Bût.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
							Grain					
182/1893 L	Cawnpore . .	11·35	4·83	18·57*	56·33	6·17	2·75	0·00	2·96	..	3·63	111·8
272/1899 L	Red variety, Poona	8·60	5·31	15·50	60·13	7·21	3·06	0·19	2·71	2·40	4·67	112·2
426/1900 L	White variety, large Kabuli, Cawnpore	10·36	4·22	22·81	57·48	1·93	3·15	0·05	4·05	3·65	2·95	125·1
635/1900 L	White variety, small, Jubbulpore	10·80	5·01	15·19	60·93	4·41	3·12	0·54	2·63	2·43	4·77	111·4
834/1902	Poona . . .	17·21	5·94	18·12*	55·36	0·73	2·64		2·90	..	3·81	115·5
298/1903	Cawnpore . .	13·43	4·41	18·38	54·65	5·85	3·28	0·00	3·05	2·94	3·52	111·6
6/1911	Military Farm, Agra	8·82	4·09	18·81	57·88	7·56	2·69	0·15	3·27	3·01	3·58	115·1
42/1912	Do. .	8·63	4·79	17·63	57·96	7·82	2·73	0·44	2·97	2·82	3·91	114·0
113/1913	Supply Reserve Depôt, Peshawar	12·92	4·61	16·36	55·81	7·52	2·75	0·03	2·69	2·62	4·06	108·2
114/1913	Supply Reserve Depôt, Peshawar	11·56	4·12	18·07	55·90	7·35	2·97	0·03	3·15	2·89	3·61	111·4
273/1914	Kirkee . . .	9·47	4·05	20·56	57·18	5·71	2·90	0·13	3·55	3·29	3·23	118·7
287/1914	Ruk . . .	9·14	4·28	19·36	56·27	7·27	3·43	0·25	3·30	3·10	3·41	115·4
293/1914	Quetta . . .	9·65	4·16	18·57	55·05	8·72	3·25	0·50	3·18	2·99	3·46	112·0
311/1914	Mhow . . .	9·72	5·10	16·90	58·41	6·70	2·93	0·24	2·87	2·70	4·15	113·3
325/1914	Jubbulpore . .	10·50	5·73	14·64	56·75	7·71	3·70	0·97	2·42	2·34	4·77	107·6
327/1914	Military Farm, Kasauli	9·09	4·03	18·58	48·49	12·20	4·13	3·58	3·35	2·97	3·10	107·5
					Flour							
517/1902	Flour with husk purchased	13·25	2·14	19·12*	55·30	7·05	3·14		3·06	..	3·15	108·5
518/1902	Flour prepared at home	13·98	2·54	21·43*	57·15	2·24	2·66		3·43	..	2·94	117·1

CICER ARIETINUM, *Linn.*—concld.

English.—Common or Bengal gram, Chick-pea.

Vernacular.—Chana, Chhola, But.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Husk						
619/1902	Gram husks . .	13·42	0·40	3·75*	35·97	42·24	4·22		0·60	..	9·84	46·4
6/1915	Gram Thoth (husk), Ambala Dairy	4·89	4·34	6·45	68·11	11·31	4·42	0·48	1·16	1·03	12·11	95·1
7/1915	Gram husk, Ambala	11·16	0·94	5·91	40·53	37·23	3·98	0·25	1·10	0·95	7·22	57·7
						Bhusa						
204/1894 L	Cawnpore . .	10·11	..	4·46	38·84	27·63	9·66	9·30	..	0·71	8·71	50·0
57/1899 L	Poona . . .	6·56	2·69	3·06	44·55	28·93	9·29	4·92	0·68	0·49	15·59	58·9
264/1899 L	Do. . . .	8·21	2·64	2·94	49·70	21·87	11·81	2·83	0·67	0·47	18·97	63·5
366/1902	Gram Bhusa . .	8·63	1·70	3·25	51·37	26·62	7·82	0·51	0·58	0·52	15·30	63·6
370/1902	Do. . .	9·88	3·08	4·25	46·10	19·93	8·18	8·58	0·83	0·68	12·51	64·4
299/1903	Cawnpore . .	11·43	1·26	2·87	42·81	28·52	8·18	4·93	0·58	0·46	15·92	53·1
300/1914	Bhusa, Bangalore .	9·36	0·89	4·44	40·36	40·40	4·24	0·31	0·75	0·71	9·55	53·7

COCOS NUCIFERA, *Linn.*

English.—Coconut.

Vernacular.—Nariyal, Narikel, Kalapa.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Cake						
23/1898 L	Poona	7·72	16·53	13·62	44·57	12·45	4·65	0·46	3·31	2·17	6·06	120·0
302/1914	Bangalore .	11·47	12·35	20·07	42·99	7·02	5·10	1·00	3·32	3·21	3·56	124·0

COIX LACRYMA-JOBI, *Linn.*

English.—Job's tears.

Vernacular.—Jargadi, Kasi, Ma-yuen.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
478/1900 L	Assam . . .	11·29	4·93	9·44	60·13	6·56	1·85	5·80	1·58	1·51	7·57	96·1

COOKED FOOD.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
102/1903	"Khichuri" (rice and tur), Cawnpore	11·68	1·05	13·44*	31·36	0·67	1·80	0·00	2·15	..	5·49	107·6
103/1903	Common bread (Roti).	22·59	1·00	7·75*	66·51	0·66	1·49	0·00	1·24	..	8·88	88·4
104/1903	"Double" bread (baked).	14·45	2·00	8·31*	71·06	0·09	2·09	0·00	1·33	..	9·10	96·8
105/1903	"Semai" (Macaroni)	13·50	2·59	8·69*	73·33	0·49	1·40	0·00	1·39	..	9·12	101·5
106/1903	"Poori" . .	18·00	8·27	9·31*	62·49	0·43	1·50	0·00	1·49	..	8·75	106·4
107/1903	"Kachawri" .	10·37	32·51	5·69*	50·24	0·10	1·09	0·00	0·91	..	2·19	145·7

CROTALARIA JUNCEA, *Linn.*

English.—Sunn-hemp.

Vernacular.—San, Sanai.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Fodder						
184/1900 L	Rajahmundry Madras	14·39	1·12	11·31	35·85	27·39	6·43	3·51	·29	1·99	8·39	66·9

Curcuma Zedoaria, *Rosc.*

English.—Long and round Zedoary.

Vernacular.—Sati.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
232/1908	Flour, Cawnpore .	19·30	0·57	0·51	79·09	0·00	0·38	0·15	0·08	..	157·45	81·[illegible]
237/1908	Starch, Curcuma Zedoaria	18·97	0·68	0·49	79·30	0·00	0·35	0·21	0·07	..	165·03	82·[illegible]

Cyamopsis psoraloides, *DC.*

English.—Cluster-bean.

Vernacular.—Guar, Khurti.

Grain

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
108/1899 L	Poona . . .	8·99	2·99	28·31	48·42	7·68	3·32	0·29	4·93	4·53	1·95	126·[illegible]
442/1900 L	Cawnpore . .	10·67	2·63	26·18	47·94	8·49	3·82	0·27	4·49	4·19	2·06	120·[illegible]
59/1911	Military Farm, Muttra	9·04	3·36	25·09	56·10	3·13	3·04	0·24	4·29	4·01	2·54	126·[illegible]

Dioscorea fasciculata, *Roxb.*

English.—Kidney-shaped yam, Karen potato.

Vernacular.—Suthni.

Tubers

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
245/1916	Suthni, Pusa village	7·38	0·64	2·75	84·24	1·28	3·61	0·10	0·56	0·44	31·17	92·[illegible]

DOLICHOS BIFLORUS, *Linn.*

English.—Horse-gram.

Vernacular.—Kulthi.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Grain						
101/1899 L	Kulthi, Poona .	7·45	0·89	20·06	60·62	4·57	4·34	2·07	3·74	3·21	3·12	113·0
173/1900 L	Do., Berhampore, Madras	10·20	0·72	16·31	63·96	3·69	3·51	1·61	3·40	2·61	4·03	106·3
560/1903	Kulthi, Matigiri (Salem)	9·98	0·93	21·94*	59·33	4·76	3·06	0·00	3·51	..	2·80	116·5
315/1914	Kulthi, Belgaum .	10·36	0·92	20·12	60·31	4·42	3·37	0·50	3·68	3·22	3·10	112 9
						Bhusa						
149/1900 L	Kulthi, Berhampore Madras	5·60	2·63	5·25	49·66	28·01	6·54	2·31	1·09	0·84	10·70	69·4
475/1902	Kulthi Bhusa	11·94	2·63	7·75	42·53	16·81	8·25	10·09	1·50	1·24	6·27	68·5

DOLICHOS LABLAB, *Linn.*

Vernacular.—Val, Popat.

						Grain						
106/1899 L	White variety, Poona	7·11	0·93	23·31	56·98	6·94	3·99	0·74	4·06	3·73	2·54	117·6
267/1899 L	White variety, Poona	9·55	2·03	23·44	53·26	7·42	4·20	0·10	4·07	3·75	2·47	116·9
268/1899 L	White "Kadawa," Poona	9·08	1·11	20·75	58·38	6·78	3·85	0·05	3·46	3·32	2·94	113·0
269/1899 L	Large white variety, "Damania," Poona	9·70	1·14	19·56	61·94	4·69	2·92	0·05	3·24	3·13	3·30	113·7
270/1899 L	"Walania," Poona	9·19	1·17	23·31	55·35	6·12	3·69	1·17	3·98	3·73	2·49	116·6
189/1900 L	Red variety Rajahmundry	12·90	1·12	17·75	57·46	7·48	3·24	0·05	3·31	2·84	3·38	104·6
252/1903	Val, Kirkee Farm .	9·28	1·16	14·44	67·36	4·01	3·75	0·00	3·26	2·31	4·85	106·4
324/1903	Lobia, Cawnpore .	12·99	1·72	22·81	54·40	4·34	3·55	0·19	3·98	3·65	2·56	115·17
						Bhusa						
263/1899 L	Val Bhusa, Poona .	9·93	3·72	13·37	43·03	16·17	11·27	2·51	2·56	2·14	3·86	85·8
						Straw						
325/1903	Lobia straw, Cawnpore	13·54	0·92	4·57	40·80	32·90	5·18	2·09	0·87	0·73	9·39	54·5

ELEUSINE CORACANA, *Gaertn.*

Vernacular.—Nagli, Ragi, Bavto, Marua.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Grain						
87/1889 L	Nagli, Poona .	9·38	1·38	5·37	78·46	2·47	2·47	0·47	0·95	0·86	15·20	95·3
47/1900 L	Do Punjab .	12·33	1·09	6·12	73·11	3·45	3·46	0·44	1·23	0·98	12·36	91·1
195/1900 L	"Bhuddai" or "Bhuda Mundya," Ganjam, Madras	14·12	1·26	7·69	66·95	3·26	2·69	4·03	1·41	1·23	9·08	89·3
196/1900 L	"Bhuda Mundya," Ganjam, Madras	13·06	1·39	6·31	66·91	2·35	2·82	7·16	1·09	1·01	11·10	86·2
197/1900 L	"Rinjya" or "Rinja Mundya," Ganjam, Madras	13·27	1·15	6·94	66·72	3·67	3·28	4·97	1·12	1·11	10·00	87·0
475/1900 L	"U Rai-trub," Hill District, Assam	14·03	1·03	6·00	74·31	2·33	2·25	0·05	1·01	0·96	12·78	91·9
589/1902	Bavto, Nadiad .	15·29	1·40	9·25*	66·54	2·66	4·26		1·48	..	7·54	92·9
590/1902	Do. do. (cleaned grain)	14·48	1·40	8·00*	71·67	2·30	2·15		1·28	..	9·36	95·2
603/1902	Nagli (cleaned) .	15·36	1·33	5·25	73·92	1·73	2·41		0·86	0·84	14·66	90·4
604/1902	Do. (uncleaned) .	15·14	1·26	5·31	73·49	2·20	2·60		0·89	0·85	14·40	89·9
604A/1902	Bavto, Nadiad .	13·47	1·05	5·94*	74·21	2·99	2·34		0·94	..	12·90	91·7
605A/1902	Do. .	13·52	1·24	5·62*	75·53	1·90	2·19		0·90	..	13·95	92·7
641/1902	Nagli, Poona . .	14·36	1·34	6·44*	73·34	1·83	2·69		1·03	..	11·87	92·8
840/1902	Do. Mysore .	13·22	1·20	5·39*	75·13	2·10	2·98		0·86	..	14·50	91·6
						Flour						
644/1902	Nagli flour, Poona .	14·77	1·19	6·87*	72·50	1·78	2·94		1·10	..	10·96	92·7

ELEUSINE CORACANA, *Gaertn.*—concld.

Vernacular.—Nagli, Ragi, Bavto, Marua.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Husk						
591/1902	Nagli husk . .	17·36	2·03	6·25	43·05	6·75	13·52	11·04	1·21	1·02	7·6	63·8
591/1902 A	Do. Nadiad .	12·94	2·05	7·50*	46·82	2·72	$\underbrace{\qquad}_{21·97}$		1·24	..	6·87	70·7
606/1902	Nagli Husk . .	17·13	1·40	6·88	54·55	9·25	9·01	1·78	1·16	1·10	8·40	75·3
606/1902 A	Do. Nadiad .	16·80	1·90	7·68*	54·08	9·34	$\underbrace{\qquad}_{10·20}$		1·22	..	7·61	78·0
643/1902	Do. Poona .	13·92	1·35	5·50*	36·58	4·55	38·10		0·88	..	7·22	53·7
841/1902	Do. Mysore .	15·50	1·50	3·75*	66·61	3·77	6·87		0·60	..	18·68	79·3
						Green fodder						
586/1900 L	" Madal," Punjab .	80·83	0·48	1·94	7·85	5·38	2·28	1·24	0·48	0·31	4·61	13·9
	Do. (dry state)	10·00	2·25	9·11	36·86	25·26	10·70	5·82	2·25	1·46	4·61	65·3

ERUCA SATIVA, *Lam*

English.—The Rocket.

Vernacular.—Tara-mira, Tara-moni, Usan, Sihuan.

						Grain						
435/1900 L	Sihuan, Cawnpore .	6·50	33·45	24·88	24·21	4·29	4·02	2·65	4·23	3·98	4·07	170·0
						Cake						
89/1902	Rocket cake, Punjab	5·94	6·35	31·25	41·45	7·84	6·03	1·14	5·37	5·00	1·79	135·5
826/1902	Tara-mira cake, Punjab	9·44	8·83	36·00*	28·48	6·86	5·52	4·87	5·76	..	1·36	140·6

FAGOPYRUM ESCULENTUM, *Moench.*

English.—Buck wheat.

Vernacular.—Phaphra, Trumba, Kootroo.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
2/1910	Phaphra, Mahammada (near Pusa)	13·04	2·36	8·75	73·32	0·56	1·72	0·25	1·48	1·40	9·00	101·1
69/1911	Kootroo (husked) Bhinga Raj, Benares	10·94	2·73	11·52	72·53	0·36	1·81	0·11	1·90	1·84	6·84	108·2
70/1911	Kootroo (unhusked)	10·86	2·63	11·59	66·98	5·50	2·09	0·35	2·10	1·85	6·30	102·5

GLYCINE SOJA, *Benth.*

English.—The Soybean.

Vernacular.—Bhat, Gari-kulay.

Soybean

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
489/1902	Soybean, Japan .	6·70	10·88	38·75*	29·75	8·69	5·23		6·20	..	1·41	153·8
490/1902	Do. do. .	6·72	11·17	43·25+	26·39	6·35	6·12		6·92	..	1·20	162·4
1013/1902	Do. Dumraon	7·57	15·55	30·12	34·87	5·21	6·48	0·20	5·72	4·82	2·35	199·1
1017/1902	Do. do.	7·66	19·72	30·75	30·41	4·50	6·66	0·30	5·46	4·92	2·46	156·6
1019/1902	Do. do. .	7·87	17·55	32·44	31·48	4·09	6·37	0·20	5·49	5·19	2·21	156·5
1023/1902	Do. Cawnpore	7·57	22·04	31·25	29·80	3·56	5·78	nil	5·44	5·00	2·58	163·0
1026/1902	Do. do. .	8·97	21·30	26·12	34·36	2·67	5·58	nil	5·40	4·18	3·19	152·9
1029/1902	Do. do. .	8·95	17·93	31·12	32·23	4·40	5·27	0·10	5·79	4·98	2·36	154·9
176/1903	Do. Siripur Farm	6·48	18·61	34·81	28·32	5·21	6·29	0·28	6·11	5·57	2·04	161·9
177/1903	Soybean, Siripur Farm	5·82	21·34	33·44	29·21	3·79	6·40	nil	5·95	5·35	2·34	166·2
28/1904	Soybean, Manjri Farm	8·21	17·47	36·62	30·17	2·26	5·27		6·80	5·86	1·92	165·4
30/1904	Soybean, Manjri Farm	6·60	20·74	29·44	33·25	3·77	6·20		5·49	4·71	2·74	158·7
38/1904	Soybean, Manjri Farm	7·36	19·02	25·19	38·65	3·55	6·23		4·89	4·03	3·27	149·2

GLYCINE SOJA, *Benth.*—concld.

English.—The Soybean.

Vernacular.—Bhat, Gari-kulay.

Laboratory No.	Description of Samples	% Moisture	% Ether extract.	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Soybean straw						
1018/1902	Soybean Bhusa, Dumraon	9·68	1·33	4·31	45·69	27·91	10·38	0·70	0·76	0·69	11·31	59·8
1022/1902	Soybean Bhusa, Dumraon	9·24	0·87	2·38	47·93	28·45	10·15	0·98	0·54	0·38	20·98	56·1
1025/1902	Soybean Bhusa, Cawnpore	9·62	3·13	5·19	46·78	21·29	10·32	3·67	0·95	0·83	10·40	67·6
1031/1902	Soybean Bhusa, Cawnpore	8·79	2·42	6·44	44·73	16·85	10·98	9·79	1·12	1·03	7·81	66·9
180/1903	Soybean straw, Siripur Farm	5·95	1·26	2·75	38·10	46·09	5·66	0·19	0·46	0·44	14·91	48·1
181/1903	Soybean straw, Siripur Farm	5·77	1·36	3·62	41·89	39·22	7·77	0·37	0·76	0·58	12·44	54·3
33/1904	Soybean, Manjri	9·84	3·29	8·12	49·20	22·20	7·00	0·35	1·93	1·29	6·99	77·7
35/1904	Do. do.	10·64	0·83	1·68	49·67	29·35	7·70	0·19	0·39	0·27	30·70	56·0

GOSSYPIUM.

English.—Cotton seed.

Vernacular.—Sarki, Kapasia, Rui, Tula.

Laboratory No.	Description of Samples	% Moisture	% Ether extract.	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Cotton seed						
20/1898 L	Cotton seed, Poona	8·48	18·33	11·74	38·78	17·53	3·92	1·22	2·57	1·87	6·90	114·0
171/1898 L	Do. Do.	6·93	14·57	11·34	35·96	25·05	4·47	1·68	2·49	1·81	6·13	100·7
172/1898 L	Do. Surat	6·83	16·51	12·54	32·54	27·11	4·23	0·24	2·86	2·00	5·62	105·2
301/1899 L	Egyptian seed	6·75	28·40	22·63	21·06	16·71	4·19	0·26	3·78	3·63	3·82	148·6

GOSSYPIUM—*contd.*

English.—Cotton seed.

Vernacular.—Sarki, Kapasia, Rui, Tula.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Cotton seed—concld.							
439/1900 L	"Hybrid," Cawnpore	9·94	17·78	15·06	31·05	22·30	3·37	0·50	2·52	2·41	4·78	113·2
440/1900 L	"Cook's Long Staple," Cawnpore	10·26	19·49	20·75	27·03	18·10	3·97	0·40	3·57	3·32	3·46	127·6
441/1900 L	"Cawnpore var." Cawnpore	9·26	18·68	16·13	35·38	16·62	3·55	0·38	2·91	2·59	4·86	122·4
579/1904	Cotton seed . .	6·41	13·68	13·12	38·34	24·59	3·79	0·07	2·44	2·10	5·32	105·3
77/1908	Cotton seed, Lucknow	6·88	23·11	16·69	32·61	15·71	4·26	0·74	2·72	2·67	5·14	132·1
78/1908	Do. Do.	6·54	14·55	15·19	39·81	19·93	3·78	0·20	2·65	2·43	4·82	114·2
43/1912	Cotton seed, Military Dairy Farm, Agra	10·86	11·57	14·07	39·79	19·67	3·81	0·23	2·65	2·25	4·72	103·9
279/1914	Cotton seed, Kirkee	7·21	19·59	17·06	33·48	16·67	4·95	1·04	2·90	2·13	4·60	125·1
308/1914	Cotton seed, crushed, Mhow	7·47	17·99	15·65	35·88	15·79	5·27	1·95	2·62	2·50	4·94	120 0
314/1914	Cotton seed, Belgaum	8·44	18·37	15·04	36·42	17·61	3·96	0·16	2·65	2·40	5·23	120·0
320/1914	Cotton seed, Jubbulpore	8·84	18·54	15·50	33·54	19·32	3·93	0·33	2·53	2·48	4·92	118·6
16/1916	Cotton seed, Varhadi, Kirkee	6·60	19·90	17·86	35·87	15·60	4·09	0·08	2·88	2·86	4·57	130·3
41/1916	Cotton seed, Varhadi, Kirkee	6·24	14·58	15·17	40·03	19·77	4·15	0·06	2·76	2·43	4·85	114·4
42/1916	Cotton seed, Varhadi, Kirkee	7·47	12·33	15·76	39·73	20·49	4·12	0·10	2·73	2·52	4·32	110·0
47/1916	Cotton seed, Varhadi, Kirkee	5·55	19·32	17·59	35·35	18·00	4·11	0·08	2·96	2·82	4·54	127·6
50/1916	Cotton seed, Varhadi, Kirkee	5·24	16·34	15·65	39·80	18·78	4·10	0·09	2·73	2·50	4·94	119·8
57/1916	Cotton seed, Varhadi, Kirkee	5·14	19·24	18·27	34·19	19·02	4·03	0·11	3·18	2·92	4·29	128·0

Gossypium—contd.

English.—Cotton seed.

Vernacular.—Sarki, Kapasia, Rui, Tula.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
	Cotton seed meal											
581/1904	Cotton seed meal (before steaming)	4·69	33·53	33·81	20·48	1·45	5·94	0·10	5·38	5·41	2·89	188·8
547/1906	Cotton seed meal, Cawnpore	6·59	10·13	14·62	40·74	9·44	10·52	7·96	2·71	2·34	4·38	102·6
271/1914	Cotton seed meal, Kirkee	7·28	8·86	28·33	38·60	9·98	6·17	0·78	4·69	4·53	2·08	131·6
282/1914	Cotton seed meal, Aden	7·38	9·97	31·45	36·06	7·37	6·38	1·39	5·26	5·03	1·88	139·6
290/1914	Cotton seed meal, Ruk	7·44	9·29	30·86	36·33	8·44	6·45	1·19	6·13	4·94	1·87	136·7
297/1914	Cotton seed meal, Quetta	8·48	8·68	31·96	35·30	8·08	6·30	1·20	5·21	5·11	1·70	136·9
305/1914	Cotton seed meal, Quetta	7·45	10·17	31·14	37·07	7·44	5·98	0·75	5·20	4·98	1·94	140·4
318/1914	Cotton seed meal, Belgaum	8·69	8·06	30·68	36·42	8·49	6·26	1·40	5·06	4·91	1·79	133·3
323/1914	Cotton seed meal, Jubbulpore	8·09	8·87	30·90	36·64	8·01	6·27	1·22	5·19	4·94	1·84	136·1
	Cotton seed hull											
272/1914	Cotton seed hull, Kirkee	8·32	5·20	6·52	49·58	26·95	3·29	0·14	1·09	1·04	9·44	78·9
283/1914	Cotton seed hull, Aden	7·98	3·57	5·07	50·87	29·32	3·04	0·15	0·87	0·81	11·65	72·4
304/1914	Cotton seed hull, Bangalore	8·68	5·05	5·93	50·06	27·44	2·75	0·09	1·11	0·95	10·40	77·5
	Cotton seed cake											
297/1902	Cotton seed cake, Quetta	6·05	12·05	36·00*	27·84	6·96	11·10		5·76	..	1·54	148·0
472/1902	Cotton seed cake, Quetta	14·31	1·36	20·94	40·17	17·87	4·58	0·79	3·55	3·35	8·07	95·9
785/1902	Cotton seed cake, (whole seed), Lahore	9·67	7·25	18·37	39·97	17·36	5·34	2·04	3·20	2·94	3·08	104·0

GOSSYPIUM—concld.

English.—Cotton seed.

Vernacular.—Sarki, Kapasia, Rui, Tula.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
				Cotton seed cake—concld.								
786/1902	Cotton seed cake, (10 per cent. husk removed), Lahore	9·65	6·57	18·81	41·60	15·81	5·32	2·24	3·37	3·00	3·01	105·[illegible]
787/1902	Cotton seed cake, (delinted and decorticated), Lahore	11·33	11·23	24·44	35·37	10·38	5·91	1·34	4·38	3·91	2·50	124·[illegible]
882/1902	Cotton seed cake, Hissar, Punjab	9·82	8·51	17·00	40·33	18·59	4·71	1·04	2·99	2·72	3·52	104·[illegible]
5/1903	Cotton seed cake, Hull, England	10·41	4·77	17·87	39·41	20·55	5·01	1·98	3·07	2·86	2·82	96·[illegible]
46/1903	Cotton seed cake, England	10·90	4·76	17·50	43·35	17·27	4·93	1·29	..	2·80	3·10	99·[illegible]
47/1903	Cotton seed cake, England	10·73	4·94	17·44	42·60	18·75	4·59	0·95	..	2·79	3·09	98·[illegible]
504/1903	Cotton seed cake	13·30	9·99	34·37	29·55	6·21	5·92	0·66	5·82	5·50	1·52	140·[illegible]
570/1904	Cotton seed cake, Kirkee (crushed in country *ghani*)	36·55	5·83	11·45	29·26	13·77	3·05	0·09	2·08	1·83	3·72	72·[illegible]
3/1911	Cotton seed cake, Military Farm, Agra	8·61	5·26	16·27	42·89	22·30	4·51	0·16	3·02	2·60	3·38	96·7
58/1911	Cotton seed cake, Military Farm, Muttra	8·32	3·92	16·02	48·18	19·28	3·99	0·29	2·91	2·56	3·57	98·0
33/1914	Cotton seed cake, Military Farm, Lahore	9·88	5·61	18·18	42·32	19·28	4·34	0·39	3·01	2·91	3·08	101·8
35/1914	Cotton seed cake, Military Farm, Ambala	7·55	7·62	19·49	42·47	14·48	5·58	2·81	3·14	3·36	3·08	110·8
292/1914	Cotton seed cake, Military Farm, Ruk	8·56	9·88	24·30	30·26	8·10	17·89	1·01	4·28	3·89	2·18	115·7
313/1914	Cotton seed cake, Military Farm, Mhow	8·48	5·13	19·88	40·29	18·72	5·59	1·91	3·26	3·18	2·62	102·8
1/1915	Cotton seed cake (undecorticated), Cawnpore	8·65	4·12	20·41	41·11	20·93	4·49	0·29	3·43	3·37	2·48	102·4

English.—Grass and Hay.

Vernacular.—Ghas, Gawat.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grass seed							
172/1908	Grass seed, Bikaner State	11·23	7·72	27·12*	50·79	0·50	2·41	0·23	4·34	..	2·53	138·0
					Grass							
144/1893 L	Grass (green) . .	11·07	0·00	2·69	45·40	32·07	2·05	6·72	..	0·47	16·88	52·1
199/1893 L	Do. Aligarh	4·75	0·00	3·06	50·87	32·04	2·39	6·89	..	0·49	16·62	58·5
391/1894 L	Grass (green), Saharanpore	47·43	0·00	2·66	22·00	22·23	2·36	3·32	..	0·42	8·27	28·7
396/1894 L	Grass (green), Aligarh	13·83	0·00	3·56	48·16	25·42	3·64	5·39	..	0·57	13·53	57·1
17/1895 L	Plumed grass, Juhi, Cawnpore	10·07	0·00	4·45	50·80	29·76	2·37	2·55	0·86	0·71	11·42	61·9
209/1895 L	Grass (cut dry), Nagpur	9·81	0·00	1·54	39·39	34·58	2·67	12·01	0·26	0·25	25·58	43·2
210/1895 L	Grass (cut green), Nagpur	9·23	0·00	2·46	44·16	31·75	1·74	10·66	0·41	0·39	17·95	50·3
295/1895 L	Grass, Kaira, Gujarat	8·72	0·00	2·45	45·87	34·48	1·10	7·38	0·45	0·39	18·72	52·0
122/1897 L	Grass, Aligarh .	6·87	0·00	5·60	48·99	30·08	3·15	5·31	1·05	0·89	8·75	63·0
368/1900 L	Grass, Navapur, Bombay	12·40	0·00	2·12	51·21	27·16	2·83	4·28	0·37	0·34	24·16	56·5
369/1900 L	Grass, Thana, Bombay	12·21	0·00	1·50	39·13	35·54	4·30	7·32	0·25	0·24	26·09	42·9
370/1900 L	Grass, Saugor, Central Provinces	10·59	0·00	2·07	49·89	28·11	2·55	6·79	0·35	0·33	24·10	53·1
371/1900 L	Grass, Jubbulpore, Central Provinces	11·78	0·00	2·31	43·51	33·66	2·38	6·36	0·37	0·37	18·84	49·3
372/1900 L	Grass, Budai, Central Provinces	11·36	0·00	1·31	44·42	35·24	1·99	5·68	0·21	0·21	33·91	47·7
374/1900 L	Grass, Kulphar .	11·89	0·00	1·37	49·94	26·86	2·09	7·85	0·22	0·22	36·45	53·4
377/1900 L	Grass, Bhopal .	10·78	0·00	0·94	43·92	34·98	1·14	8·24	0·15	0·15	46·72	46·3

English.—Grass and Hay.—contd.

Vernacular.—Ghas, Gawat.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio
					Grass—contd.						
378/1900 L	Grass, Hiranin .	11·58	0·00	1·31	46·33	31·80	2·14	6·84	0·22	0·21	35·37
379/1900 L	Grass, Sohagpore .	10·91	0·00	1·37	48·24	32·98	1·54	4·96	0·29	0·22	35·21
283/1901 L	Grass (yellowish), Cawnpore	9·03	0·93	4·88	41·05	33·57	4·05	6·49	0·93	0·78	8·85
284/1901 L	Grass (greenish), Cawnpore	9·06	1·89	4·19	39·83	34·09	3·48	7·46	0·67	0·51	10·54
828/1906	Grass, Ambala .	7·45	0·99	7·62	32·42	35·65	8·19	7·68	1·30	1·22	4·55
26/1908	Grass (forest), Sandhaur	12·15	1·62	1·73	45·84	33·54	2·28	2·84	0·28	0·27	28·65
27/1908	Grass (forest), Kans	10·98	1·72	2·84	46·92	32·59	2·12	2·83	0·47	0·45	17·92
28/1908	Do. Kus . .	10·54	1·06	2·72	44·99	34·87	1·99	3·83	0·46	0·44	17·44
29/1908	Do. Ganrar .	12·31	1·19	1·91	44·85	33·48	2·77	3·49	0·40	0·31	24·92
30/1908	Grass (general admixture)	9·87	2·75	2·50	44·26	34·19	2·48	3·95	0·44	0·40	20·24
38/1908	Grass (forest), Bundelkhand	8·82	1·07	2·38	48·22	31·59	2·46	5·46	0·49	0·38	21·29
39/1908	Grass (forest), Bundelkhand	7·58	1·14	1·39	49·21	31·42	1·97	7·29	0·28	0·22	37·29
251/1908	Grass, Barrackpore	7·39	1·63	2·63	43·25	38·60	2·44	4·06	..	0·40	17·86
252/1908	Do. Do.	7·00	1·18	5·94	44·17	18·35	8 95	14·41	..	0·95	7·89
7/1909	Grass (kessari), Lucknow	7·06	1·90	3·19	48·60	32·15	3·01	4·09	..	0·51	16·61
263/1909	Grass (fodder), Muttra	8·16	0·55	2·50	47·10	36·82	4·12	0·75	0 61	0·40	19·35
16/1910	Grass, Muttra .	6·25	1·82	4·69	51·56	30·57	1·75	3·36	0·81	0·75	11·89
18/1910	Do. Do. .	7·36	1·33	2·06	48·83	32·81	2·61	5·00	0·36	0·33	25·19
22/1910	Do. Barrackpore	8·08	1·16	3·95	49·17	30·16	2·38	5·10	0·67	0·63	13·42

English.—Grass and Hay.—contd.

Vernacular.—Ghas, Gawat.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grass—contd.							
139/1910	Grass, Bareilly .	11·47	1·72	2·46	48·72	29·30	2·54	3·79	0·42	0·39	21·41	59·2
148/1910	Do. Agra .	9·95	1·43	0·63	49·32	30·67	1·06	6·94	0·20	0·10	83·51	54·5
157/1910	Do. Do. .	10·17	1·62	5·98	50·57	23·46	4·52	3·68	1·14	0·96	9·08	69·6
167/1910	Do. Meerut .	13·83	1·53	5·66	47·39	24·06	3·38	4·15	1·16	0·91	8·00	65·4
168/1910	Do. Do.	11·85	1·42	2·68	50·21	24·40	1·95	7·49	0·47	0·43	19·96	60·5
218/1910	Do. Ranikhet .	9·64	1·92	3·38*	49·80	28·64	2·63	3·99	0·55	..	16·04	63·1
219/1910	Do. Do. .	10·53	2·91	2·80*	51·50	27·24	1·99	3·13	0·43	..	20·75	65·7
50/1911	Do. Nowshera .	7·72	0·83	4·23	49·42	21·68	5·69	10·43	0·75	0·68	12·13	62·1
52/1911	Do. Do. .	7·82	1·97	2·28	49·89	29·87	2·10	6·07	0·38	0·37	23·87	60·5
62/1911	Do. Lucknow .	7·44	1·92	1·48	49·66	31·83	1·58	6·09	0·30	0·24	36·54	58·2
63/1911	Do. Do. .	7·41	1·44	1·75	49·03	29·95	2·15	3·27	0·30	0·28	29·91	57·0
143/1911	Do. Nainital .	36·81	1·00	2·41*	30·80	23·88	3·12	1·98	0·39	..	13·73	39·3
144/1911	Do. Do. .	24·28	1·14	3·56*	37·39	28·91	2·58	2·14	0·57	..	11·24	49·1
145/1911	Do. Do. .	19·80	0·83	2·25*	40·16	32·15	1·79	3·02	0·36	..	18·70	47·9
146/1911	Do. Do. .	21·57	1·14	2·69*	39·34	31·45	1·90	1·91	0·43	..	15·60	48·9
60/1913	Grass, Marvale, Hyderabad	7·90	1·64	2·98	47·10	31·21	1·91	7·26	0·50	0·58	17·07	58·7
61/1913	Grass, Pownia, Hyderabad	7·54	1·28	1·84	46·04	28·37	2·79	12·14	0·45	0·30	26·62	53·8
62/1913	Grass, Rowsa, Hyderabad	8·05	2·05	1·71	48·46	33·40	2·00	4·33	0·29	0·27	31·11	57·9

English.— Grass and Hay.—contd.

Vernacular.—Ghas, Gawat.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio
					Grass—concld.						
63/1913	Grass, Gundali, Hyderabad	7·97	1·35	2·23	49·47	29·75	3·04	6·19	0·42	0·36	23·58
94/1913	Grass, Barrackpore	11·67	1·47	5·12	55·08	19·34	4·33	2·99	0·95	0·82	11·42
127/1915	Grass, Meerut (cut from shady plot)	8·24	1·31	2·56	50·46	29·40	1·96	6·07	0·46	0·41	20·89
129/1915	Grass, Meerut (cut from open and dry plot)	5·43	1·22	3·71	46·43	34·05	2·36	6·80	0·77	0·59	13·27
130/1915	Grass, Sirwala (cut from open and dry plot), Meerut	4·51	0·93	1·82	48·48	37·15	1·70	5·41	0·36	0·29	27·81
136/1915	Grass, Sirwala (cut from shady plot), Meerut	5·14	1·01	2·65	46·75	35·91	2·00	6·54	0·45	0·42	18·52
142/1915	Grass, Sirwala (cut from open and dry plot)	4·45	1·06	2·24	47·92	33·68	1·94	6·71	0·45	0·36	22·48
7/1916	Grass (Nevla), Kirkee	7·38	1·78	1·90	53·41	26·81	4·00	4·72	0·35	0·30	30·26
8/1916	Grass (Arsenal), Kirkee	6·31	1·95	2·68	45·93	32·62	2·30	8·21	0·47	0·43	18·81
9/1916	Grass (Arsenal), Kirkee	7·13	1·54	3·40	43·03	30·34	2·03	12·53	0·59	0·54	13·70
104/1916	Grass (Rhodes), Jubbulpore	1·59	1·48	4·47	45·09	34·66	9·73	2·98	1·99	0·72	10·85
							Hay				
4/1904	Hay, Cawnpore .	9·78	1·14	3·50	55·71	20·39	4·74	4·74	0·63	0·56	16·67
1089/1904	Hay, Agra, United Provinces	8·04	0·00	2·94	54·68	23·57	4·39	6·38	0·57	0·47	18·60
630/1907	Hay, Gonda, United Provinces	9·69	1·36	2·25	46·72	33·08	2·45	4·45	0·40	0·36	22·16
637/1907	Hay, Bundelkhand	7·95	1·28	1·71	51·25	31·24	2·63	3·94	0·35	0·27	31·69
639/1907	Do. Do. .	9·64	1·23	1·32	48·10	32·00	2·34	5·37	0·27	0·21	38·58
643/1907	Do. Do. .	8·53	1·28	2·26	45·57	31·66	2·30	8·40	0·44	0·36	21·46

English.—Grass and Hay.—concld.

Vernacular.—Ghas, Gawat.

Laboratory No.	Description of Samples	Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Hay—concld.							
08	Hay, Bahraich, United Provinces	9·48	1·50	1·63	48·52	31·81	2·61	4·45	0·28	0·26	31·88	56·4
08	Hay, Gorakhpur .	9·27	1·70	2·09	48·21	30·80	2·43	5·50	0·36	0·33	24·94	57·7
8/08	Do. Ambala .	10·25	1·60	3·06	42·38	30·38	3·23	9·10	0·50	0·44	15·05	54·0
3/08	Do. Do. .	10·06	2·46	11·16	38·12	26·32	9·81	2·07	2·03	1·79	3·92	72·2
6/08	Do. Do. .	10·34	1·51	3·12	43·98	32·83	3·56	4·66	0·64	0·50	15·21	55·6
1/13	Do. Meerut . .	7·01	1·46	2·45	46·18	30·22	1·78	10·90	..	0·39	20·22	56·0
2/13	Do. Do. . .	6·62	1·32	1·67	47·69	27·82	2·27	12·61	..	0·27	30·38	55·2
3/13	Do. Do.	6·35	1·97	1·97	48·35	30·12	1·90	9·34	..	0·32	26·84	58·2
4/13	Do. Do. . .	9 27	1·29	2·77	50·53	29·69	2·19	4·26	0·46	0·44	19·31	60·7
5/16	Hay (*Cynodon dactylon*), Jubbulpore	3·04	1·45	7·22	55·18	24·74	5·37	3·00	1·51	1·16	8·10	76·9

GUIZOTIA ABYSSINICA, *Cass.*

English.—Niger seed.

Vernacular.—Kala til, Ram til, Surguja.

					Grain							
72/394 L	Niger seed, Poona .	6·15	41·14	20·07*	15·08	12·10	4·37	1·09	3·24	..	5·47	168·1
73/395 L	Do. Lucknow	8·43	38·20	19·25*	11·49	15·19	4·36	3·08	3·08	..	5·16	155·1
3/99 L	Do. Poona .	4·88	38·03	19·31	17·47	9·20	6·69	4·42	3·19	3·09	5·43	160·8
32/02	Do. Saugor .	7·70	9·32	29·94	28·95	14·70	7·04	2·35	4·97	4·79	1·68	127
						Oil cake						
36/99 L	Niger seed cake, Poona	7·42	9·30	38·56*	25·48	10·03	6·25	2·96	6·17	..	1·22	145·1

Helianthus annuus, *Linn.*

English.—Sunflower.

Vernacular.—Surajmukhi.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates.	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio
						Oil cake					
312/1914	Belgaum . .	8·38	7·35	18·02	57·87	1·96	4·23	2·19	3·05	2·88	4·15

Hordeum vulgare, *Linn.*

English.—Barley.

Vernacular.—Jav.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates.	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio
						Grain					
164/1893 L	Local white, Cawnpore	13·74	1·80	8·29*	70·32	3·49	1·76	0·60	1·33	..	8·98
165/1893 L	Local black, Cawnpore	12·55	1·93	7·73*	69·71	5·63	0·85	1·60	1·24	..	9·59
166/1893 L	Chocolate, Cawnpore	12·79	1·97	8·24*	73·23	1·73	1·89	0·15	1·32	..	9·44
168/1893 ·	White huskless, Cawnpore	12·18	1·83	7·92*	74·12	2·10	1·00	0·85	1·26	..	9·89
4/1898 L	Local black, Cawnpore	11·85	1·84	8·04*	72·65	3·24	1·99	0·39	2·29	..	9·56
423/1900 L	Local white, Cawnpore	11·40	1·83	6·62	73·52	4·29	1·72	0·62	1·17	1·06	10·23
424/900 L	White huskless, Cawnpore	11·44	1·63	12·50	70·44	1·86	1·95	0·18	2·13	2·00	5·94
7/1911	Military Farm, Agra	9·32	2·46	8·38	71·44	5·67	1·51	1·22	1·39	1·34	9·20
192/1913	Crushed barley, Peshawar	8·74	1·89	9·23	73·16	4·13	1·80	1·05	1·55	1·48	8·40
280/1914	Kirkee . .	10·32	2·26	7·73	73·02	4·49	1·71	0·47	1·31	1·24	10·12
291/1914	Ruk .	9·38	2·19	8·81	69·72	5·37	2·39	2·14	1·46	1·41	8·49
296/1914	Quetta	10·48	2·12	8·51	70·43	5·27	2·00	1·19	1·38	1·36	8·85

HORDEUM VULGARE, *Linn.*—contd.

English.—Barley.

Vernacular.—Jav.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Meal						
117/1906	Cawnpore . .	10·64	2·42	13·48	70·27	1·07	1·87	0·25	2·30	2·16	5·63	110·0
						Bhusa						
202/1893 L	Cawnpore . .	7·93	..	4·00	41·45	34·82	5·55	6·25	..	0·64	10·36	51·5
444/1900 L	Do. . .	12·07	1·38	7·81	39·99	24·56	9·19	5·00	1·28	1·25	5·52	63·0
						Green fodder						
229/1900 L	Green barley, Punjab	79·66	0·45	2·46	8·20	6·54	2·14	0·55	0·46	0·40	3·76	15·5
	Green barley, dry state	10·31	1·98	10·85	36·16	28·84	9·44	2·42	2·03	1·76	3·75	68·2
101/1916	Green barley (dried)	3·62	1·54	5·81	43·26	34·25	8·47	3·05	1·46	0·93	8·05	61·6

IPOMŒA BATATAS, *Lamk.*

English.—Sweet Potato.

Vernacular.—Alua, Sakarkand, Ranga-alu, Ratalu.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
56/1915	Tilaitia, red . .	9·50	1·64	1·57	82·26	1·64	3·35	0·04	0·31	0·25	54·79	90·3
57/1915	Mongla, white .	8·39	0·82	1·66	83·54	1·95	3·56	0·08	0·33	0·28	51·46	89·7
58/1915	Jhighunia, flesh-coloured	7·67	0·75	1·55	85·91	1·46	2·62	0·04	0·29	0·25	56·54	91·7
59/1915	Gajirva, red . .	7·59	0·92	2·29	83·69	1·46	4·01	0·04	0·44	0·37	37·47	91·7
60/1915	Panma, white, very big	6·50	1·03	5·40	80·54	1·52	4·92	0·09	1·17	0·95	15·54	96·6
246/1916	Panma, white, very big	6·16	1·23	1·87	85·40	2·05	3·19	0·10	0·39	0·30	47·18	93·2
247/1916	Panma, white, very big	5·05	1·23	2·77	86·00	1·76	3·06	0·13	0·49	0·44	32·07	96·0
248/1916	Panma, white, very big	7·26	1·27	2·59	84·03	1·78	2·91	0·16	0·52	0·41	33·57	93·7
249/1916	Panma, white, very big	4·86	1·36	2·48	86·35	1·76	3·09	0·10	0·57	0·40	36·00	96·0
250/1916	Panma, white, very big	5·22	1·42	3·41	84·47	2·06	3·32	0·10	0·70	0·55	26·10	96·6

Lathyrus sativus, *Linn.*

English.—Chickling-Vetch.

Vernacular.—Khesari, Lakh, Lang, Teora.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Grain						
107/1899 L	Poona . . .	7·89	0·79	24·69	57·98	4·28	3·18	1·19	4·21	3·95	2·42	121·7
						Bhusa						
56/1899 L	Poona . . .	6·10	5·00	9·75	45·39	19·36	9·49	4·91	1·96	1·56	5·84	82·3
265/1899 L	Do. . . .	11·08	2·93	9·25	43·03	20·57	10·46	2·68	1·66	1·32	5·60	73·5

Lens esculenta, *Moench.*

English.—Lentil.

Vernacular.—Masur.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Grain						
103/1899 L	Poona . .	8·03	1·06	23·00	61·14	2·42	3·54	0·81	3·94	3·68	2·76	121·3
						Bhusa						
373/1902	Masur bhusa . .	10·23	1·80	4·37	50·03	21·36	10·82	1·39	0·86	0·70	12·39	65·5

Linum usitatissimum, *Linn.*

English.—Linseed.

Vernacular.—Alsi, Masina, Tisi.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Seed						
94/1899 L	Brown variety, Poona	4·97	37·47	20·92	26·24	5·60	3·96	0·84	3·71	3·35	5·37	172·2
436/1900 L	Brown variety, Cawnpore	6·62	43·16	15·00	26·01	4·94	3·67	0·60	2·67	2·40	8·35	171·4
						Meal						
307/1914	Mhow . . .	3·56	41·34	17·45	26·43	5·71	3·82	1·69	2·99	2·79	6·96	173·4

LINUM USITATISSIMUM, *Linn.*—concld.

English.—Linseed.

Vernacular.—Alsi, Masina, Tisi.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and Silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Cake						
492/1902	Linseed cake . .	21·71	2·46	27·19	32·46	6·42	6·67	3·09	4·50	4·35	1·40	106·6
519/1902	Do. . .	10·45	9·42	26·69	40·26	6·32	5·47	1·39	4·35	4·27	2·32	130·5
594/1902	Do. . .	16·24	8·90	30·44	32·39	4·90	5·65	1·48	5·05	4·87	1·74	130·7
941/1902	Do. . .	8·63	11·72	26·75	39·68	6·06	5·79	1·37	4·28	4·11	2·49	135·9
285/1914	Do. Aden	7·77	11·59	37·22	26·04	2·85	10·09	4·44	6·41	5·96	1·42	148·1
312/1914	Do. Mhow	8·58	10·57	30·72	36·73	6·72	5·33	1·35	5·25	4·92	1·99	140·0
322/1914	Linseed cake, Jubbulpore	8·70	13·19	27·02	37·59	6·59	5·32	1·59	4·80	4·32	2·51	138·1

MEDICAGO SATIVA, *Linn.*

English.—Lucerne, Alfalfa.

Vernacular.—Vilayti-gawuth.

						Green fodder						
51/1899 L	Poona . . .	77·75	0·76	3·60	11·89	3·74	2·75	0·11	0·71	0·48	4·55	21·29
53/1899 L	Do. . . .	78·32	0·75	3·81	11·21	3·35	2·44	0·12	0·81	0·61	3·40	22·61
232/1916	Baled, Quetta .	3·14	3·32	15·48	46·30	17·70	11·83	2·23	2·98	2·48	3·49	93·3
240/1916	Dried in country fashion, Quetta	5·00	2·90	11·71	43·87	27·95	8·10	0·47	2·19	1·87	4·40	80·4

MELILOTUS PARVIFLORA, *Desf.*

Syn.—TRIFOLIUM INDICUM.

English.—Senji.

						Green fodder						
231/1900 L	Punjab . . .	84·40	0·36	2·69	6·16	4·13	1·87	0·39	5·15	0·43	2·60	13·8
	Dry state . .	10·00	2·08	15·52	35·54	23·83	10·79	2·25	2·97	2·47	2·60	79·5

MISCELLANEOUS.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Mixed rape and cotton cake							
784/1902	Lahore . . .	9·79	8·21	26·50	40·07	10·86	3·23	1·34	4·27	4·24	2·23	126·8
237/1907	Do. . . .	9·10	7·40	22·06*	40·54	13·97	5·50	1·43	3·53	..	2·61	114·2
					Mixed groundnut and niger seed cake							
17/1902	Poona . . .	7·32	9·12	42·06	25·42	8·19	6·45	1·44	6·97	6·73	1·01	153·4
61/1902	Nasik . .	9·44	8·14	29·94	28·52	14·17	6·89	2·90	4·98	4·79	1·58	123·7
					Mixed oil cake							
840/1904	Hyderabad, Sind .	5·87	11·42	31·91	35·08	8·16	6·07	1·49	5·60	5·10	1·92	143·4
212/1906	Ambala . .	9·47	9·86	28·81	34·79	9·09	5·87	1·23	5·25	4·61	1·99	131·5
213/1906	Do. . .	8·78	10·24	28·35	35·83	9·04	5·93	1·83	5·02	4·54	2·09	132·3
					Prickly pear							
575/1902	Poona . . .	16·96	..	2·94*			21·81	0·59	0·47			
					Molascuit.							
72/1908	Lucknow . .	13·46	..	1·30	70·74	7·96	5·98	0·56	..	0·21	54·42	74·0
					Mixed gram and barley							
60/1911	Muttra . . .	9·49	2·74	12·71	67·03	5·40	1·92	0·71	2·26	2·03	5·77	105·7
					Mixed Bhusa							
376/1909	Daryal Bhusi, Allahabad	10·38	3·73	4·84	61·32	14·93	3·03	1·77	1·72	0·77	14·44	82·8
100/1912	Nowshera . .	6·01	1·42	3·08	44·40	29·89	4·28	10·92	0·57	0·50	15·48	55·7
102/1912	Do. . .	4·58	1·36	3·34	45·79	31·77	4·18	8·98	0·59	0·53	14·65	57·5
159/1916	Sialkot . .	1·28	1·16	2·68	48·12	34·80	2·05	9·91	..	0·48	18 91	57·7

ORYZA SATIVA, *Linn.*

English.—Paddy, Rice.

Vernacular.—Dhan, Dangar, Bhatta, Chaval, Nellu.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain undecorticated							
198/1900 L	Patcha Bhoga, Madras	12·87	2·38	7·07	64·06	7·21	1·39	5·02	1·18	1·13	9·83	87·7
206/1900 L	Chandanchur, Dinajpur	11·72	2·25	5·82	66·83	7·78	1·30	4·30	1·08	0·93	12·37	87·0
212/1900 L	Bhogantara, Backerganj	13·82	2·04	6·00	62·16	9·64	1·13	5·21	1·03	0·96	11·14	82·3
218/1900 L	Sufeda, Jalalabad, Punjab	12·73	1·88	6·44	64·47	8·29	1·35	4·84	1·05	1·03	10·68	85·3
226/1900 L	Khasira, Amritsar, Punjab	12·64	2·08	5·44	65·84	7·90	1·45	4·65	0·95	0·87	12·98	84·6
457/1900 L	Panekekoa, long stemmed, Assam	12·87	2·05	6·06	65·81	8·07	1·54	3·60	1·07	0·97	11·64	86.1
459/1900 L	Ranga Ahu, Assam	12·92	1·78	7·38	63·42	8·20	1·50	4·80	1·28	1·18	9·15	86·3
274/1900 L	Rosangi, Godavari, Madras	11·85	2·25	4·82	65·66	9·28	1·57	4·57	0·97	0·77	14·70	83·3
476/1902	Tasu of mataya dhan	11·26	1·13	3·69*	31·81	31·38	1·58	19·15	0·59	..	9·30	43·9
478/1902	Konda of Malaya dhan	13·64	1·65	6·81*	39·09	19·29	3·29	16·23	1·09	..	6·30	60·2
480/1902	Konda of Kulia dhan	12·76	1·36	4·81*	38·45	24·87	2·50	15·25	0·77	..	8·64	53·9
481/1902	Matwa of rice .	13·60	2·20	6·75*	34·25	25·13	3·57	14·50	1·08	..	5·82	56·6
					Grain decorticated							
36/1900 L	Fine winter, Bengal	12·46	0·94	6·38	79·25	0·18	0·69	0·10	1·33	1·02	12·76	97·6
38/1900 L	Coarse winter, Burdwan	12·00	1·26	6·44	78·46	0·23	0·95	0·66	1·06	1·03	12·63	97·7
144/1900 L	Basmati of Kandi, Gurdaspur	11·28	0·80	5·50	80 81	0·23	0·83	0·55	1·04	0·88	15·03	96·6
146/1900 L	Jhona, Gurdaspur, Punjab	10·90	1·04	5·75	80·15	0·58	0·84	0·74	0·93	0·92	14·35	97·1
171/1900 L	Daluva, Ganjam, Madras	11·51	1·03	6·69	78·50	0·27	0·70	1·30	1·15	1·07	12·09	97·8
172/1900 L	Coarse paddy, Ganjam	11·56	0·59	6·13	79·98	0·36	0·81	0·57	1·06	0·98	13·27	96·8

ORYZA SATIVA, *Linn.*—contd.

English.—Paddy, Rice.

Vernacular.—Dhan, Dangar, Bhatta, Chaval, Nellu.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain decorticated—concld.							
458/1900 L	Panikekoa, Assam .	13·75	0·91	7·25	76·77	0·18	1·05	0·09	1·25	1·16	10·88	97·2
460/1900 L	Ranga Ahu, Assam	13·78	1·23	9·32	73·35	0·62	1·54	0·16	1·54	1·49	8·17	99·7
611/1902	Rice, cleaned . .	12·66	1·17	6·43*	78·63	0·25	0·86		1·03	..	12·68	97·6
612/1902	Do. Kanki .	13·31	1·29	7·62*	76·55	0·40	0·83		1·22	..	10·44	98·8
	Hemcha, Sabour .	12·45	2·44	8·64	74·44	0·57	1·46		1·38	1·36	9·27	102·1
	C. P. Aus, Bankipore	12·28	2·19	7·56	75·28	0·95	1·74		1·21	1·20	10·62	99·7
	Kalamdan, Dumraon	11·14	2·40	6·06	78·36	0·50	1·54		0·97	0·97	13·84	99·5
	Badshabhog Do.	11·44	2·59	8·63	74·60	0·90	1·84		1·38	1·37	9·33	102·7
					Rice, polished							
	Hemcha, Sabour .	10·76	0·60	8·25	80·26	0·13	0·60		1·32	1·31	9·90	102·4
	C. P. Aus, Bankipore	11·60	1·14	7·39	78·91	0·05	0·91		1·18	1·16	10·90	100·2
	Kalamdan, Dumraon	11·83	0·85	5·69	80·42	0·35	0·86		0·91	0·90	14·48	96·8
	Badshabhog, Do.	12·08	0·99	8·63	77·37	0·10	0·83		1·38	1·38	9·23	101·4
						Rice dust						
274/1914	Rice sweepings, Kirkee	9·64	2·59	9·26	74·17	1·51	1·74	1·09	1·59	1·48	8·65	103·8
319/1915	White rice dust, Kasauli	11·07	3·05	11·90	60·42	1·94	5·83	5·79	2·22	1·90	5·66	97·8
						Rice bran						
566/1900 L	Bran mixed with husks, Madras	7·98	7·06	5·50	32·98	27·44	3·40	15·64	1·01	0·88	8·95	64·4
567/1900 L	Bran mixed with husks, Madras	8·44	9·56	5·94	35·53	22·91	3·71	13·91	1·06	0·95	9·68	74·3
						Rice husk						
36A/1900 L	Fine winter, Bengal	9·33	5·43	4·81	40·15	22·14	2·73	15·41	1·06	0·77	10·94	65·8
38A/1900 L	Coarse winter, Burdwan	6·73	3·04	4·12	34·32	25·31	2·57	23·91	0·74	0·66	10·03	52·2

ORYZA SATIVA, *Linn.*—concld.

English.—Paddy, Rice.

Vernacular.—Dhan, Dangar, Bhatta, Chaval, Nellu.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter.	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Rice husk—concld.						
144A/1900 L	Basmati of Kandi, Gurdaspur, Punjab	7·67	3·59	4·06	40·95	25·04	3·30	15·39	0·66	0·65	12·12	60·1
546/1900 L	Rosangi, Godavari, Madras	8·76	1·24	4·19	30·86	32·12	2·14	20·69	0·75	0·67	8·05	44·4
548/1900 L	Daluva, Madras .	8·56	1·38	3·13	33·54	29·67	2·48	21·24	0·53	0·49	11·73	44·8
549/1900 L	Daluva, Madras, after boiling	9·59	1·39	3·32	33·89	29·96	2·12	19·73	0·59	0·53	11·17	45·7
526/1902	Husk of Basmati rice	9·74	0·59	3·44*	25·22	32·98	1·99	26·04	0·55	..	8·31	35·3
527/1902	Do. Parusa rice	10·16	0·87	2·75*	31·37	33·04	1·49	20·32	0·44	..	12·13	40·5
						Straw						
37/1900 L	Fine winter, Bengal	9·46	0·95	1·81	40·54	30·30	6·23	10·71	0·33	0·29	23·61	47·4
39/1900 L	Coarse winter, Bengal	9·51	1·25	2·25	40·89	30·64	5·01	10·45	0·38	0·36	19·45	49·6
199/1900 L	Patcha bhogo, Madras	9·08	1·34	3·19	39·29	27·74	3·19	14·17	0·53	0·51	13·28	50·6
202/1900 L	Kohala, Madras .	12·09	1·79	3·54	42·80	24·08	2·81	12·89	0·72	0·57	13·25	56·1
209/1900 L	Kataribhog, Dinajpur	11·14	1·08	3·19	39·95	28·64	3·47	12·53	0·59	0·51	13·30	50·6
364/1902	Basmati rice straw .	9·07	1·57	4·87*	40·52	28·91	4·25	10·81	0·78	..	9·06	56·6
367/1902	Dilhaka dhan .	9·75	0·52	2·81*	29·55	38·86	1·26	17·25	0·45	..	10·94	37·9

PANICUM CRUS-GALLI, *Linn.*; VAR. FRUMENTACEUM, *Trimen.*

English.—Poorman's millet.

Vernacular.—Sama, Banti.

					Grain							
80/1899 L	Poona . . .	7·72	4·39	7·06	67·56	7·44	1·70	4·13	1·18	1·13	11·00	96·2

PANICUM MAXIMUM, *Jacq.*

Syn. PANICUM JUMENTORUM, *Pers.*

English.—Guinea grass.

Vernacular.—Gini gawat.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Green fodder							
50/1899 L	Poona . . .	63·38	0·84	1·88	19·36	8·79	2·60	3·15	0·41	0·30	11·32	26·2
52/1899 L	Do. . . .	71·55	1·05	2·62	13·71	5·73	1·87	3·46	0·53	0·42	6·16	22·9

PANICUM MILIACEUM, *Linn.*

English.—Common millet.

Vernacular.—Varágu, China, Vari.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain							
88/1899 L	Poona . .	7·95	4·11	6·81	67·26	7·63	2·16	4·08	1·18	1·09	11·26	94·6
97/1899 L	Do. . . .	8·57	5·09	9·38	64·21	6·30	2·50	3·95	1·52	1·50	8·06	100·4
45/1900 L	Punjab . . .	9·99	4·52	7·94	64·13	8·24	1·83	3·35	1·39	1·27	9·39	95·3
633/1902	Vari . .	12·62	4·40	7·31*	64·19	8·99	2·49		1·17	..	10·17	93·5
636/1902	Vari cleaned grain .	12·47	1·44	7·93*	76·66	0·39	1·20		1·27	..	10·08	100·1
						Chaff						
634/1902	Chaff before grinding	12·54	3·94	10·12*	55·80	8·72	8·88		1·62	..	6·41	91·0
635/1902	Do. after do. .	12·10	6·54	7·18*	45·76	21·65	6·77		1·15	..	8·47	80·1

Panicum miliare, *Lamk.*

English.—Little millet.

Vernacular.—Shamai, Sava, Kutki, Gondula, Kungu.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain							
637/1902	Sava	12·98	5·33	9·06*	60·93	7·57	4·13		1·45	..	8·12	96·9
640/1902	Sava cleaned grain	12·92	1·79	9·50*	74·65	0·35	0·79		1·52	..	8·29	102·9
					Chaff							
638/1902	Sava chaff before grinding	12·25	3·94	9·06*	53·60	13·76	7·39		1·45	..	9·61	86·1
639/1902	Sava chaff after grinding	11·11	9·76	7·18*	39·13	21·41	11·41		1·15	..	8·57	81·5

Papaver somniferum, *Linn.*

English.—Poppy.

Vernacular.—Kashkash, Postadana.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Seed							
438/1900 L	Cawnpore	4·07	48·95	17·75	16·99	5·09	6·85	0·30	2·97	2·84	7·30	183·7

Paspalum scrobiculatum, *Linn.*

English.—Kodo millet.

Vernacular.—Kodon, Kodra, Harik.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain							
85/1899 L	Poona	8·01	3·36	5·81	70·06	8·47	1·34	2·95	1·00	0·93	13·32	93·0
613/1902	Kodra cleaned	12·84	1·29	8·06*	75·28	0·55	1·98		1·29	..	9·71	98·7
615/1902	Kodra	11·71	2·85	8·75*	64·72	9·14	5·83		0·92	..	8·15	93·7
65/1903	Kolaba No. 1	10·21	3·29	6·34	68·00	8·20	1·98	1·98	1·09	1·01	11·92	92·1

PASPALUM SCROBICULATUM, *Linn.*—concld.

English.—Kodo millet.

Vernacular.—Kodon, Kodra, Harik.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter.	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain—concld.							
66/1903	Kolaba No. 2 .	8·46	3·41	6·36	66·41	10·95	2·05	2·36	1·07	1·02	11·67	90·8
68/1903	Ratnagiri . .	9·07	3·94	5·46	70·77	9·37	0·30	1·09	0·99	0·87	14·80	94·
70/1903	Do. . .	8·71	2·90	6·31	71·02	8·92	1·24	0·90	1·04	1·01	12·31	94·
71/1903	Do. . .	8·83	3·17	6·19	69·75	9·32	1·15	1·59	1·14	0·99	12·45	93·
73/1903	Do. . .	8·04	3·13	5·81	68·69	11·65	1·39	1·29	1·00	0·93	13·06	91·
75/1903	Do. . .	7·43	2·46	5·31	69·47	9·98	2·48	2·87	0·88	0·85	14·15	93·
					Husk							
614/1902	Kodra husk after grinding	10·56	3·28	4·87*	71·10	2·19	8·00		0·78	..	16·15	91·

PENNISETUM TYPHOIDEUM, *Rich.*

English.—Bulrush millet, Spiked millet.

Vernacular.—Bajra, Kambu.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter.	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Grain						
81/1899 L	"Mahdodhri," Poona	8·05	5·36	9·88	74·26	0·60	1·60	0·25	1·72	1·58	8·76	112·
84/1899 L	"Bhownuggri," Poona	8·60	5·37	9·37	73·94	0·86	1·68	0·18	1·58	1·41	9·21	110·
91/1899 L	"Awned," Poona .	8·09	5·50	10·00	72·99	0·62	2·12	0·68	1·70	1·60	8·56	111·
95/1899 L	Nadiad, Poona .	8·87	5·08	8·62	74·75	0·90	1·59	0·19	1·47	1·38	10·03	109·
96/1899 L	Local variety, Poona	8·96	5·75	8·12	74·11	0·93	1·74	0·39	1·34	1·30	10·76	108·
43/1900 L	Punjab . . .	10·08	4·93	11·12	71·07	0·76	1·64	0·40	1·86	1·78	7·41	111·
626/1902	Bajra . . .	14·30	5·16	8·75*	67·87	1·34	2·58		1·40	..	9·11	102·
						Flour						
627/1902	Purchased . .	12·84	3·88	8·43*	70·72	1·39	2·74		1·35	..	9·45	101·
628/1902	Home made . .	13·54	3·74	8·75*	71·19	1·39	1·39		1·40	..	9·11	102·

PHASEOLUS ACONITIFOLIUS, *Jacq.*

English.—Aconite-leaved kidney bean.

Vernacular.—Moth, Matti-kalai, Bhringga.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain							
105/1899 L	Poona	8·59	1·07	22·50	58·85	4·24	3·99	0·76	4·01	3·60	2·73	117·8
48/1900 L	Punjab	7·46	0·83	20·50	63·55	3·83	3·58	0·25	3·75	3·28	3·19	116·9
480/1900 L	Rim-bai-ja, Assam	13·78	0·67	17·00	59·34	5·73	3·43	0·05	2·97	2·72	3·52	103·5
					Bhusa							
43/1903	Lahore	8·78	2·80	12·13	47·12	14·20	10·48	4·49	2·21	1·94	4·42	84·5
					Green fodder							
584/1900 L	Punjab	74·70	0·89	3·20	12·00	4·99	2·95	1·27	0·68	0·51	4·39	22·2
	Dry state	10·00	3·16	11·36	42·60	17·71	10·47	4·70	2·43	1·82	4·39	78·9

PHASEOLUS LUNATUS, *Linn.*

English.—Lima bean, Duffin bean, Burma bean.

Vernacular.—Pegyi, Banbarbati.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
129/1903	From Tempesby & Co.	9·13	1·15	15·50	65·82	4·71	3·69	0·00	2·83	2·48	4·42	107·5
244/1903	Burma	10·00	1·15	12·69	67·94	4·17	3·86	0·19	2·80	2·03	5·56	102·5
245/1903	Do.	9·53	0·89	14·56	66·80	4·15	3·78	0·29	3·12	2·33	4·73	105·4
248/1903	Burma (Sagaing District).	10·29	1·28	14·06	66·37	3·83	3·98	0·19	3·08	2·25	4·93	104·7
251/1903	Burma (Pakoku District)	10·03	1·22	12·69	67·89	3·76	4·23	0·18	3·09	2·03	5·57	102·7
279/1903	From Morrison and Downs.	13·60	1·32	11·35	65·11	4·86	3·66	0·10	2·65	1·82	6·00	96·8
280/903	Gillespi & Co.	14·44	1·25	12·69	63·59	4·45	3·48	0·10	2·82	2·03	5·24	98·4

PHASEOLUS LUNATUS, *Linn.*—concld.

English.—Lima bean, Duffin bean, Burma bean.

Vernacular.—Pegyi, Banbarbati.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
281/1903	Rangoon market .	14·53	0·92	13·69	62·66	4·42	3·78	0·00	2·92	2·19	4·73	99·2
282/1903	Morrison and Downs	10·79	1·41	13·35	66·29	4·27	3·89	0·00	3·21	2·14	5·21	103·2
283/1903	Gillespi & Co. .	16·92	0·92	11·87	63·09	3·65	3·55	0·00	3·06	1·89	5·49	95·1
284/1903	Rangoon market .	16·97	0·95	12·19	62·56	3·70	3·63	0·00	3·06	1·95	5·31	95·4

PHASEOLUS MUNGO, *Linn.*

Vernacular.—Urid, Mash-kalai.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Grain						
100/1899 L	Poona . .	8·14	0·99	18·50	59·11	4·33	4·51	4·42	3·24	2·96	3·40	107·8
50/1900 L	Green variety, Punjab	11·05	0·96	20·13	60·82	3·48	3·17	0·39	3·51	3·22	3·13	113·6
51/1900 L	Black variety, Punjab	9·69	1·13	22·81	59·36	3·27	3·54	0·20	3·75	3·65	2·72	119·2
185/1900 L	"Black grain," Madras	9·97	0·82	21·81	59·64	3·77	3·24	0·75	3·77	3·49	2·82	116·2
479/1900	"Mati m[illegible]b," Assam	10·99	0·83	20·50	59·03	4·79	3·58	0·30	3·64	3·28	2·97	112·4
323/1903	Cawnpore . .	11·67	1·02	22·32	57·52	3·38	3·50	0·59	3·74	3·57	2·68	115·9
						Bhusa						
186/1900 L	Black grain bhusa, Madras	15·96	1·70	11·19	39·14	17·08	9·97	4·96	2·03	1·79	3·85	71·4
375/1902	Urid bhusa . .	9·89	1·13	6·13	41·86	32·58	7·03	1·38	1·30	0·98	7·25	60·0
41/1903	Lahore . . .	8·97	2·56	14·50	44·11	10·62	8·87	10·37	2·48	2·32	3·45	61·2
328/1903	Cawnpore .	10·92	1·91	8·94	35·82	11·47	9·57	21·37	1·54	1·43	4·50	62·9

Phaseolus radiatus, *Linn.*

English.—Green gram.

Vernacular.—Mug, Mung.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Grain						
104/1899 L	Poona . . .	9·48	1·83	23·56	56·39	4·42	4·02	0·30	4·03	3·77	2·57	119·9
49/1900 L	Mung, Punjab .	10·02	0·93	22·94	58·94	3·38	3·74	0·05	3·76	3·67	2·66	118·6
187/1900 L	Pessara, Godavari .	11·64	0·79	20·82	58·72	4·04	3·99	0·90	4·17	3·33	2·91	112·7
200/1900 L	Muggo, Ganjam, Madras.	9·79	0·86	20·12	61·67	3·71	3·52	0·33	3·75	3·22	3·16	114·1
417/1900 L	Cawnpore . .	11·00	0·96	18·69	62·19	3·43	3·22	0·51	3·41	2·99	3·45	111·3
						Bhusa						
188/1900 L	Rajahmundry, Madras	13·30	2·52	10·88	40·35	18·66	10·38	3·91	1·85	1·74	4·24	73·9
474/1902	Mung bhusa . .	9·27	2·03	8·56	39·45	18·76	8·77	13·16	1·43	1·37	5·15	65·9
42/1903	Lahore . . .	9·50	2·43	11·81	45·93	14·83	10·60	4·90	2·10	1·89	4·36	81·5

Pisum arvense, *Linn.*

English.—Grey or Field Pea.

Vernacular.—Karain, Mattar rewari.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Grain						
428/1900 L	Cawnpore . .	10·56	0·93	20·12	61·34	4·46	2·54	0·05	3·45	3·22	3·16	114·0
						Green fodder						
102/1916	Field Pea (Fodder) .	4·56	2·42	9·93	44·84	28·48	9·11	0·66	3·35	1·59	5·40	75·7

PISUM SATIVUM, *Linn.*

English.—Garden Pea.

Vernacular.—Bara-mattar, Bahtahna.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Grain						
180/1893 L	White, Cawnpore .	12·05	1·27	24·12*	54·44	5·47	2·65	0·00	3·84	..	2·38	117·9
181/1893 L	Black, Do. .	11·27	1·47	24·67*	52·47	6·67	3·30	0·15	3·95	..	2·26	117·8
99/1899 L	Vatane, Poona .	7·89	1·40	20·06	62·12	5·69	2·79	0·05	3·38	3·21	3·26	115·8
420/1900 L	Do. Cawnpore .	11·42	1·17	21·00	57·84	5·43	3·05	0·09	3·87	3·36	2·88	113·3
637/1900 L	Do. Jubbulpore	11·05	1·06	19·00	61·86	3·26	2·99	0·78	3·31	3·04	3·38	112·0
						Bhusa						
58/1899 L	Poona . . .	7·27	3·02	11·75	42·43	19·36	9·65	6·52	2·49	1·88	4·20	79·4

RICINUS COMMUNIS, *Linn.**

English.—Castor.

Vernacular.—Arand, Bherenda.

						Seed						
430/1900 L	Large variety, Cawnpore.	7·43	45·28	14·00	10·59	19·58	2·94	0·18	2·36	2·24	8·20	158·8
						Cake						
63/1902	Surat . . .	11·83	7·18	30·06	25·02	19·69	5·57	0·65	5·05	4·81	1·38	118·1
294/1902	Broach . . .	7·55	7·07	29·31	29·63	19·73	5·57	1·14	4·82	4·69	1·57	120·6
326/1902	Surat . . .	12·37	4·50	27·56	18·08	29·71	6·84	0·94	5·05	4·41	1·03	98·2

* Although not used for feeding purposes, this is included here for the sake of comparison with edible oil-cakes.

SACCHARUM OFFICINARUM, *Linn.*

English.—Sugarcane.

Vernacular.—Ukh, Ak, Ganna, Oos.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter,	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Cane						
73/1908	Sugarcane (fodder), Lucknow	31·85	1·03	1·01	37·76	21·56	2·23	4·56	0·19	0·16	39·73	42·9
						Molasses						
71/1908	Molasses, Lucknow	11·29	0·00	1·52	65·84	14·78	4·97	1·60	..	0·24	4·33	69·6
						Leaf						
2/1916	Sugarcane leaf, Bangalore	7·27	1·47	3·12	47·38	34·40	4·27	2·09	0·55	0·50	16·27	58·9

SESAMUM INDICUM, *DC.*

English.—Gingelly, Sesame.

Vernacular.—Til.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter,	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Seed						
86/1897 L	White var., Ahmednagar.	4·48	48·13	22·50*	14·05	4·49	5·59	0·37	3·60	..	5·54	190·6
87/1897 L	Black var., Nadiad.	5·43	46·50	25·81*	9·06	6·51	6·03	0·66	4·13	..	4·50	189·8
88/1897 L	Red var., Ahmednagar.	5·37	46·20	21·03*	15·87	4·18	6·00	1·35	3·37	..	5·81	184·0
86/1899 L	Red var., Poona .	4·18	49·12	20·37	14·16	2·93	6·65	2·59	3·34	3·26	6·24	187·9
89/1899 L	Black var., Do. .	4·14	47·60	18·12	18·56	4·14	6·85	0·59	3·11	2·90	7·07	182·9
98/1899 L	White var., Do. .	4·21	51·96	18·06	14·62	4·49	6·28	0·38	2·99	2·89	7·43	189·7
54/1900 L	Black var., Punjab .	5·57	52·27	17·94	13·26	3·87	6·58	0·51	3·06	2·87	7·44	188·8
55/1900 L	White var., Do. .	5·53	48·53	21·37	13·96	3·56	6·56	0·49	3·68	3·42	5·88	188·7
431/1900 L	Black var., Cawnpore	4·82	47·11	20·00	15·86	5·20	6·34	0·67	3·39	3·20	6·21	183·6

SESAMUM INDICUM, *DC.*—concld.

English.—Gingelly, Sesame.

Vernacular.—Til.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Seed—contd.						
432/1900 L	White var., Cawnpore	4·91	48·00	19·69	15·60	5·15	6·32	0·33	3·36	3·15	6·40	184·8
433/1900 L	Do. Do.	4·51	48·45	19·00	16·22	4·33	6·60	0·89	3·23	3·04	6·72	184·9
822/1902	Til seed	5·67	44·56	19·00*	13·51	4·74	12·52	0·00	3·04	..	6·11	172·4
						Oil cake						
169/1898 L	Red var., Poona	10·39	14·12	29·46	29·91	3·88	8·52	3·72	5·81	4·71	2·12	138·9
170/1898 L	Black var., Do.	10·07	10·90	31·66	29·59	10·30	5·77	1·71	6·15	5·06	1·73	136·0
15/1902	Oil cake, Do.	9·05	15·14	36·31	25·00	3·96	8·95	1·59	6·03	5·81	1·65	153·6
62/1902	Do. Surat	11·20	10·90	33·63	26·09	7·83	8·66	1·69	5·69	5·38	1·52	137·4
66/1902	Do. Khandesh	7·36	11·87	29·88	31·21	8·69	9·50	1·49	5·41	4·78	1·96	135·6
90/1902	Do. Punjab	6·95	8·08	37·31	29·80	3·67	11·59	2·60	6·29	5·97	1·30	143·3
263/1902	Til oil cake, Saugor	6·50	7·22	32·56	36·80	4·18	10·09	2·65	5·49	5·21	1·64	136·3
293/1902	Do. Broach	8·34	15·13	34·44	24·87	2·98	10·79	3·45	5·88	5·51	1·73	148·8
327/1902	Do. Surat	13·41	6·41	35·31	28·16	6·81	9·31	0·59	6·16	5·65	1·22	132·5
518/1902 A	Do. Raipur	13·69	11·29	33·18	25·45	3·61	10·50	2·28	5·63	5·31	1·55	136·6
535/1902	Do. Rollputti	15·13	8·36	30·31	30·30	3·00	10·86	2·04	5·13	4·85	1·63	127·0
592/1902	Do. Sambalpur.	14·64	8·62	33·43	27·51	3·96	9·59	2·25	5·67	5·35	1·42	132·6
595/1902	Do. Chanda	16·23	3·60	35·37	27·50	4·40	11·46	1·44	6·07	5·66	1·01	124·9
844/1902	Do. Madras.	20·29	6·49	48·38	13·94	2·55	6·76	1·59	7·79	7·74	0·60	151·1
1/1911	Do. Agrà	7·40	8·50	36·35	31·58	4·99	9·96	1·22	6·15	5·82	1·41	143·7
326/1914	Do. Jubbulpore.	7·74	17·12	33·18	24·07	2·25	0·65	4·99	5·55	5·31	1·91	149·8
4/1915	Do Cawnpore.	10·07	16·32	41·63	22·35	2·34	6·77	0·52	7·19	6·66	1·44	167·2

SETARIA ITALICA, *Beauv.*

English.—Italian millet.

Vernacular.—Rala, Kangni.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
						Grain						
78/1899 L	"Rala," Poona .	7·75	4·54	10·37	69·19	5·22	1·44	1·49	1·68	1·66	7·68	106·5
44/1900 L	"Kangni," Punjab	10·11	4·96	10·50	63·81	6·29	1·74	2·59	1·75	1·68	7·16	102·5
46/1900 L	"Swaux," Punjab .	10·25	4·33	10·62	65·37	6·18	2·25	1·00	2·07	1·70	7·09	102·8
477/1900 L	W. "Rai-Soh," Hill district, Assam.	11·96	3·46	10·25	62·79	6·23	2·98	2·33	1·72	1·64	6·90	97·1
630/1902	Rala grain (cleaned)	12·17	4·14	10·00*	63·48	8·64	1·57		1·60	..	7·30	98·8
						Chaff						
631/1902	Rala chaff (before grinding).	12·48	2·84	9·37*	54·40	16·06	4·85		1·50	..	6·50	84·9
632/1902	Rala chaff (after grinding).	13·26	5·18	6·87*	40·59	22·92	11·18		1·10	..	7·64	70·7
					Green	*fodder*						
585/1900 L	Kangni (fresh), Punjab.	76·79	0·54	2·08	10·08	6·37	1·82	2·32	4·81	3·32	5·44	16·6
	Kangni (dry), Punjab.	10·00	2·09	8·07	39·11	24·71	7·02	9·00	1·86	1·28	5·44	64·5

SILAGE.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
208/1895 L	Air-dry silage, Nagpur	12·08	0·00	2·53	40·52	33·95	1·58	9·34	0·47	0·41	16·02	46·9
122/1901	Maize silage (fresh state), Nagpur	81·87	0·21	0·77	9·44	5·50	1·10	1·11	0·17	0·12	12·88	11·9
〃	Maize silage (air-dry)	7·66	1·07	3·93	48·02	28·06	5·60	5·66	0·90	0·63	12·84	60·5
123/1901 L	Sorghum silage (fresh)	60·52	0·65	1·89	21·37	11·29	1·59	2·69	0·33	0·30	12·10	27·7
–	Sorghum silage (air-dry)	5·72	1·55	4·58	51·10	26·87	3·80	6·43	0·79	0·72	12·07	66·3
5291/1906	Silage of Sundhia juar	4·60	2·53	4·25	53·74	24·71	4·52	5·65	1·03	0·68	14·01	70·7
646/190	Silage (fresh) . .	51·69	1·96	2·87	21·05	15·52	2·93	3·98	0·81	0·46	8·91	33·1
106/1916	Silage . . .	6·10	1·48	5·31	42·31	32·22	6·04	6·54	0·90	0·85	8·61	59·3

SORGHUM VULGARE, *Pers.*

English.—The Indian or Great Millet, Guinea corn.

Vernacular.—Juar, Cholam, Janera.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain.							
23/1896 L	Juar grain, Nagpur	9·96	7·66	7·69	70·15	2·24	1·67	0·63	1·26	1·23	11·41	10
63/1898 L	Juar grain, (white fine), Surat	12·04	3·06	7·10	74·45	1·39	1·64	0·32	1·21	1·13	11·47	[illegible]
64/1898 L	Juar grain (white fine) (2nd class), Surat	11·55	3·50	6·00	76·70	0·96	1·24	0·05	1·05	0·96	14·12	10
65/1898 L	Juar grain (red cheap-grain), Surat	12·08	3·22	9·92	71·47	1·17	1·87	0·27	1·67	1·58	7·95	10
273/1899 L	Juar grain, "Khend," Poona	9·98	3·61	11·87	71·54	1·12	1·83	0·05	1·96	1·81	6·73	11
278/1899 L	Juar grain, "Nilwa," Poona	10·41	4·45	11·19	70·99	1·18	1·73	0·05	1·91	1·79	7·26	11
279/1899 L	Juar grain, "Dudh Mogra," Poona	10·21	4·13	10·19	71·90	1·22	2·11	0·24	1·74	1·63	7·99	10
280/1899 L	Juar grain, "Mal Dandi," Poona	8·76	3·47	9·57	74·20	1·75	1·92	0·33	1·65	1·53	8·59	10
281/1899 L	Juar grain, "Sundia," Poona	9·90	4·59	12·44	70·05	0·79	1·83	0·40	2·11	1·99	6·48	11
42/1900 L	Juar grain (brown), Punjab	11·33	3·16	8·94	71·88	2·09	1·90	0·70	1·49	1·43	8·85	10
56/1900 L	Juar grain (white), Punjab	12·04	3·13	8·19	73·44	1·37	1·64	0·19	1·34	1·31	9·85	10
404/1900 L	Juar grain (red), Gazipore	11·25	3·29	9·44	73·37	1·56	1·81	0·28	1·62	1·51	8·47	10
405/1900 L	Juar grain (white), Agra	11·71	3·84	7·99	72·99	1·36	1·82	0·29	1·34	1·27	10·24	10
406/1900 L	Juar grain (white), Cawnpore	11·37	3·58	8·19	73·46	1·66	1·64	0·10	1·39	1·31	9·97	10
407/1900 L	Juar grain (dwarf brown), Cawnpore	10·86	3·39	8·81	73·40	1·81	1·68	0·05	1·48	1·41	9·22	10
623/1902	Do. do.	14·41	3·23	8·31*	70·64	1·59	1·82	0·00	1·33	..	9·39	9
624/1902	Juar flour (Purchased)	14·29	2·53	8·25*	71·66	1·44	1·83	0·00	1·32	..	9·39	9
625/1902	Juar flour (Home made)	14·68	2·43	9·31*	70·33	1·39	1·86	0·00	1·49	..	8·15	9

SORGHUM VULGARE, *Pers.*—contd.

English.—The Indian or Great Millet, Guinea corn.

Vernacular.—Juar, Cholam, Janera.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Grain—concld.							
300/1903	Juar grain, Cawnpore	14·02	3·06	5·75	73·41	1·19	1·72	0·85	1·21	0·92	13·99	95·4
320/1903	Do. do.	13·33	3·04	7·44	72·70	1·22	1·78	0·49	1·19	1·29	10·70	98·9
326/1903	Do. do.	13·88	2·88	6·94	72·72	1·29	2·00	0·29	1·21	1·11	11·43	97·3
					Green fodder							
356/1895 L	Juar (sundried sample), Aligarh	8·35	0·00	4·19	47·85	33·59	3·28	2·74	0·70	0·67	11·42	58·3
19/1896 L	Juar (reaped green), Nagpur	69·76	0·00	0·55	14·74	11·90	1·17	1·88	0·11	0·09	26·80	16·1
21/1896 L	Juar (reaped ripe), Nagpur	67·02	0·00	0·64	16·42	12·78	1·52	1·62	0·17	0·10	25·66	18·0
24/1896	Juar (dead ripe), Nagpur	10·79	0·00	2·24	51·57	25·42	3·04	6·94	0·49	0·36	23·02	57·2
317/1896 L	Juar (cut in October), Cawnpore	56·10	0·00	3·10	20·65	15·32	2·29	2·54	0·56	0·50	6·66	28·4
318/1896 L	Juar (cut in March), Cawnpore	63·77	0·00	1·54	18·50	10·35	1·77	4·07	0·42	0·25	2·01	22·4
319/1896 L	Do. do.	48·78	0·00	2·01	25·31	15·92	2·10	5·88	0·43	0·32	12·59	30·3
27/1898 L	Juar (cut in March), Madras	80·24	0·46	1·21	9·71	6·15	1·09	1·14	0·23	0·19	8·90	13·9
583/1900 L	Juar (cut in March), Punjab	80·27	0·51	1·24	8·87	6·18	1·51	1·42	0·24	0·20	8·10	13·3
6/1916	Kerbi (Juar) green, Ruk	3·75	1·42	4·28	52·61	30·50	5·11	2·33	1·04	0·68	13·06	66·9
10/1916	Kerbi (Juar), Nilwa, Ruk	3·78	1·83	1·44	49·60	35·79	5·91	1·65	0·43	0·23	37·37	57·8
					Straw							
301/1903	Juar straw, Cawnpore.	10·63	1·43	2·38	42·80	20·90	4·27	17·59	0·39	0·38	19·37	52·3
321/1903	Do. do.	13·09	2·43	2·56	45·58	23·75	4·66	7·93	0·54	0·41	19·99	58·4
327/1903	Do. do.	12·20	1·84	2·19	45·91	23·58	4·36	9·92	0·42	0·35	22·89	56·0

Sorghum vulgare, *Pers.*—concld.

English.—The Indian or Great Millet, Guinea corn.

Vernacular.—Juar, Cholam, Janera.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Bhusa							
9/1898 L	Juar Bhusa, Nagpur	12·61	0·00	2·24	45·95	25·42	3·22	10·56	0·48	0·36	20·51	51
174/1898 L	Juar Bhusa, "Sundhia" (not quite ripe), Poona	8·04	2·19	3·83	47·98	27·90	2·91	7·15	0·64	0·61	13·48	63
175/1898 L	Juar Bhusa, "Kowbi" (not quite ripe), Poona	7·35	2·11	2·29	46·27	31·38	3·45	7·15	0·41	0·37	22·32	57
148/1900 L	Juar Bhusa, Samalkota, Madras	7·63	3·09	4·50	44·67	21·64	3·42	15·05	0·81	0·72	11·51	63

Sorghum vulgare *var.* saccharatus, *Pers.*

English.—Sugar Sorghum, Amber Cane.

Vernacular.—Deo-dhan.

					Green fodder							
18/1896 L	Deo-dhan (reaped green), Nagpur	70·96	0·00	0·81	12·14	12·57	1·23	2·29	0·18	0·13	14·99	1
20/1896 L	Deo-dhan (reaped ripe), Nagpur	57·15	0·00	1·22	19·17	18·13	1·29	3·04	0·26	0·19	15·71	2
20/1915	Deo-dhan, Karnal .	7·36	1·90	3·70	59·15	21·12	3·88	2·89	0·68	0·59	17·17	7

Trifolium alexandrinum, *Linn.*

English.—Egyptian clover.

Vernacular.—Berseem.

12/1916	Green fodder . .	6·48	2·77	22·04	34·44	15·52	16·32	2·43	4·80	3·53	1·85	9
103/1916	Do .	2·60	1·85	10·94	41·46	30·60	11·73	0·82	2·70	1·75	4·17	7

TRIFOLIUM RESUPINATUM, *Linn.*

English.—Persian clover.

Vernacular.—Shaftal.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and Silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
92/16	Shaftal hay, Quetta.	15·86	2·19	14·10	39·98	13·80	12·88	1·19	2·48	2·26	3·19	80·7
15/16	Shaftal (from Usar spot), Quetta	21·91	2·44	14·27	39·41	10·80	10·18	0·99	2·70	2·28	3·15	81·2
16/16	Shaftal (from normal area), Quetta	22·15	2·43	13·56	38·80	10·58	11·70	0·76	2·63	2·17	3·27	78·8

TRITICUM VULGARE, *Vill.*

English.—Wheat.

Vernacular.—Gehum.

Grain

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and Silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
51/893 L	Country, bearded, Cawnpore	13·35	1·73	8·47*	73·08	1·57	1·75	0·05	1·36	..	9·10	98·6
52/893 L	Country, beardless, Cawnpore	13·19	1·60	9·75*	72·03	1·93	1·40	0·10	1·56	..	7·76	100·4
54/893 L	Sindhi, Cawnpore	12·21	1·66	9·92*	72·68	1·73	1·80	0·00	1·59	..	7·71	101·6
05/900 L	Gangajali, Bengal, red, hard	13·78	1·89	9·57	70·25	2·33	1·84	0·34	1·77	1·50	7·80	98·9
91/900 L	Dudhia, Banka, Bengal, white, soft	16·11	1·75	9·44	68·55	2·35	1·62	0·18	1·62	1·53	7·69	96·5
93/900 L	Dudhia, Palamau, white, soft	14·36	1·91	10·19	65·54	2·61	3·35	2·04	1·76	1·63	6·86	95·8
420/900 L	"Muzaffarnagar" Cawnpore white, soft	11·58	1·70	8·13	75·22	1·23	2·04	0·10	1·38	1·30	9·73	99·8
421/900 L	Kathya, Cawnpore, white, soft	11·00	1·53	9·25	73·65	1·33	2·99	0·25	1·66	1·48	8·34	100·6
422/900 L	"Rust proof," Cawnpore, white, hard	9·94	1·50	9·25	75·96	1·50	1·80	0·05	1·57	1·48	8·59	102·8
485/900 L	Kheri, Malda, red, hard	13·52	2·20	10·06	68·76	2·93	2·26	0·27	1·73	1·61	7·34	99·4
487/900 L	Gangajali, Malda, red, hard	13·51	1·60	11·88	68·55	2·33	1·90	0·23	2·01	1·90	6·08	102·3

TRITICUM VULGARE, *Vill.*—contd.

English.—Wheat.

Vernacular.—Gehum.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and Silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio
					Grain—concld.						
480/1900 L	"Jamali," Barb, Bengal, red, soft	14·26	1·88	10·69	68·25	2·30	2·15	0·47	1·82	1·71	6·79
491/1900 L	"Champapuri," Darbhanga, red, soft	13·27	2·11	12·69	66·75	2·93	2·06	0·19	2·14	2·03	5·64
497/1900 L	"Dudhia," Patna, white, soft	13·86	1·82	10·00	69·44	2·71	2·03	0·14	1·73	1·60	7·36
505/1900 L	"Dudhia," Gaya, white, soft	13·73	1·74	10·63	68·53	2·07	2·22	1·08	1·85	1·70	6·82
507/1900 L	Jamali, Gaya, red, soft	13·40	1·71	8·87	71·69	2·39	1·80	0·14	1·55	1·42	8·53
513/1900 L	"Champapuri," Gaya, red, soft	12·77	1·98	11·00	69·27	2·15	2·36	0·47	1·89	1·76	6·71
516/1900 L	"Naubia," Arariah, red, hard	12·64	1·21	10·50	70·58	2·67	2·19	0·21	1·81	1·68	6·99
645/1902	Wheat . . .	13·07	1·80	13·50*	66·95	2·19		2·49	2·16	..	5·27
296/1903	Cawnpore . .	12·89	1·75	8·44	73·73	1·52	1·48	0·19	1·41	1·35	9·21
312/1903	Do. . .	14·21	1·75	7·13	73·44	1·59	1·69	0·19	1·23	1·14	10·86
					Flour						
647/1902	Wheat flour . .	13·17	1·40	13·50*	68·23	1·20	2·50		2·16	..	5·29
380/1909	Lucknow . .	10·77	2·21	14·29	67·50	2·28	2·66	0·29	2·60	2·29	5·08
173/1910	Military Dairy, Lucknow.	10·95	2·57	9·38	73·31	1·83	1·83	0·13	1·80	1·50	8·44
					Flour mill waste						
25/1908	Ambala . .	11·35	4·62	12·21	54·57	11·00	3·87	2·38	2·14	1·95	5·34
64/1911	Military Farm, Agra	7·93	2·23	7·98	67·93	9·82	2·74	1·37	1·54	1·28	9·15
65/1911	Do. do.	8·06	5·06	11·22	68·70	4·17	2·45	0·34	2·06	1·80	7·16
46/1912	Do. do.	9·85	2·61	12·00	68·25	3·63	2·47	1·19	1·98	1·92	6·19
47/1912	Do. do.	9·32	2·36	9·54	66·35	8·20	2·77	1·46	1·71	1·53	7·52

Triticum vulgare, *Vill.*—contd.

English.—Wheat.

Vernacular.—Gehum.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Wheat product.							
88/914	Dust, Ruk . .	7·27	1·71	4·83	50·29	14·71	7·78	13·41	0·89	0·77	11·23	66·7
95/914	Do. Quetta . .	7·59	1·63	4·66	49·60	14·65	7·71	14·16	0·81	0·75	11·45	65·3
98/914	Ground, Quetta .	10·07	2·40	11·24	68·92	3·84	2·58	0·95	1·99	1·80	6·62	103·0
99/914	Dalia, Quetta .	9·39	2·97	10·57	66·25	5·06	3·14	2·62	1·85	1·69	6·91	100·1
24]/914	Thin, Jubbulpore .	7·89	9·45	10·37	37·79	3·51	10·26	20·73	1·83	1·66	5·74	87·3
8/915	Sloth, Ambala .	10·76	1·90	8·22	64·61	9·18	3·04	2·29	1·48	1·32	8·39	89·9
9/915	Do. Lahore .	6·37	2·02	6·32	44·08	12·40	5·94	22·87	1·15	1·01	7·71	64·9
10/915	Dust, Ambala .	9·04	1·39	6·44	53·53	12·59	5·28	11·73	1·18	1·03	8·81	73·1
11/915	Do. Lahore . .	9·80	1·01	6·57	54·34	14·82	5·27	8·19	1·20	1·05	8·62	73·3
13/915	Pollard, Lahore .	10·95	3·30	11·01	66·83	4·38	3·32	0·21	1·93	1·76	6·76	102·6
318/915	Fine pollard, Ambala	12·61	3·37	10·42	68·74	2·32	2·37	0·17	1·99	1·67	7·34	103·1
						Bran						
2/1898 L	Dehra Dun .	12·93	4·94	7·56	65·78	5·47	3·14	0·18	1·45	1·21	10·20	97·0
129/1898 L	Poona . . .	11·88	4·19	10·90*	58·66	9·37	4·56	0·44	1·74	..	6·27	96·4
648/1900 L	Roller mills, Bombay	13·44	3·07	10·30	56·58	10·83	5·36	0·42	1·82	1·65	6·18	90·0
649/1900 L	Hand chaky, Bombay.	12·96	2·34	16·10	57·40	7·20	3·60	0·40	2·78	2·57	3·90	103·5
276/1914	Bran, Kirkee . .	9·07	4·11	11·93	62·22	6·32	4·80	1·55	2·08	1·91	6·00	102·3
284/1914	Do. Aden . .	8·33	4·04	11·61	63·20	7·58	5·09	0·15	2·05	1·86	6·24	102·3
289/1914	Do. Ruk . .	9·56	4·65	12·87	60·47	6·89	5·32	0·24	2·28	2·06	5·53	104·3

TRITICUM VULGARE, *Vill.*—contd.

English.—Wheat.

Vernacular.—Gehum.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albminoid ratio	Food units
					Bran—	concld.						
294/1914	Barn, Quetta	10·03	4·32	13·97	59·64	7·16	4·67	0·21	2·40	2·23	4·98	10
306/1914	Do. Bangalore	9·13	3·78	12·87	63·46	6·19	4·38	0·19	2·32	2·06	5·61	10
309/1914	Do. Mhow	9·22	3·74	11·33	60·64	8·65	4·65	1·77	1·92	1·86	6·11	9
316/1914	Do. Belgaum	10·82	3·17	11·39	61·69	8·12	4·64	0·17	2·02	1·82	6·05	9
319/1914	Do. Jubbulpore	10·83	3·97	12·14	60·61	7·98	4·24	0·23	2·08	1·94	5·74	10
15/1915	Do. Karnal	10·09	2·48	8·72	64·15	9·37	4·10	1·09	1·47	1·39	8·00	9
17/1915	Do. Ambala	10·83	4·12	11·63	60·72	7·43	4·54	0·73	2·03	1·86	6·03	10
18/1915	Do. Allahabad	10·28	3·81	12·02	60·85	8·28	4·59	0·17	2·07	1·92	5·79	10
					Straw							
355/1895 L	Gursikran	7·61	..	3·04	35·33	45·93	3·34	4·75	0·65	0·49	11·62	42
443/1900 L	Cawnpore	9·53	0·74	2·44	40·19	35·43	4·47	7·20	0·53	0·39	17·17	48
498/1900 L	Dudhia, Patna	9·20	0·99	3·75	37·98	31·68	4·15	12·25	0·71	0·60	10·74	49
508/1900 L	Jamati, Gaya	9·13	1·32	3·32	37·17	30·51	4·69	13·86	0·59	0·53	12·11	48
514/1900 L	Champapuri, Gaya	8·17	1·06	3·38	37·12	30·80	4·36	15·11	0·67	0·54	11·70	48
517/1900 L	Naubia, Arariah	8·06	0·80	2·13	39·81	39·78	3·82	5·60	0·37	0·34	19·55	47·
365/1902	Pissi wheat straw	8·56	1·46	2·75	45·07	28·38	5·04	8·74	0·51	0·44	17·61	55·
460/1902	Wheat straw	9·85	1·90	3·12	49·80	24·89	2·98	7·46	0·49	0·49	17·36	62·
309/1903	Cawnpore	10·74	1·14	1·44	47·06	27·23	3·00	9·39	0·34	0·23	34·50	53·
313/1903	Do.	10·40	1·49	2·62	37·87	19·18	4·76	23·68	0·48	0·42	15·76	48·

Triticum vulgare, *Vill.*—concld.

English.—Wheat.

Vernacular.—Gehum.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid ratio	Food units
					Straw—concld.							
317/903	Cawnpore . .	11·75	1·55	3·37	40·22	22·40	5·08	15·63	0·55	0·54	13·00	52·5
29/903	Do. . .	12·27	1·25	2·00	44·86	23·76	3·99	11·87	0·41	0·32	23·86	53·0
					Green fodder.							
228/900 L	Punjab . .	82·65	0·40	1·87	7·56	5·07	1·52	0·93	0·32	0·30	4·54	13·2
	Dry state . .	10·01	2·07	9·70	39·24	26·31	7·84	4·83	1·66	1·56	4·54	68·7

Vicia sativa, *Linn.*

English.—Common vetch, Tare.

Vernacular.—Akta.

					Grain							
	Akta, Pusa . .	9·08	1·06	25·74	54·96	5·78	3·10	0·18	4·65	4·12	2·23	122·0

Vigna Catjang, *Walp.*

English.—Cow pea.

Vernacular.—Lobia, Chavli, Barbati.

					Grain							
102/1899 L	Poona . .	7·26	1·35	20·13	63·30	4·07	3·41	0·48	3·68	3·22	3·30	117·0
52/1900 L	Rawan, Punjab .	10·45	1·42	16·81	65·31	2·33	3·58	0·10	2·72	2·69	4·08	110·0

ZEA MAYS, *Linn.*

English.—Maize, Indian corn.

Vernacular.—Makai, Bhutta.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid nitrogen	Food units
					Grain							
40/1900 L	Maize grain (white), Punjab	11·83	4·53	8·25	72·03	1·16	1·95	0·25	1·42	1·32	9·99	10
41/1900 L	Maize grain (orange), Punjab	11·98	4·49	7·37	72·58	1·03	2·45	0·10	1·27	1·18	11·25	10
410/1900 L	Maize grain, local (yellow), Cawnpore	10·54	4·73	9·38	72·53	1·43	1·34	0·05	1·57	1·51	8·89	10
411/1900 L	Maize grain, "Jaunpore" (white), Cawnpore	8·04	5·13	9·32	74·33	1·53	1·60	0·05	1·53	1·49	9·24	11
412/1900 L	Maize grain "King Philip," (large, red, imported), Cawnpore	10·72	4·22	11·62	70·29	1·46	1·59	0·10	1·88	1·86	6·89	10
413/1900 L	Maize grain, Early American, (large, white, imported), Cawnpore	11·02	4·29	9·57	72·20	1·33	1·39	0·20	1·62	1·53	8·58	10
414/1900 L	Maize grain extra early large, orange imported), Cawnpore	10·59	4·69	9·69	71·96	1·43	1·54	0·10	1·63	1·56	8·54	10
415/1900 L	"Sweat Corn," (Large white, imported), Cawnpore	9·94	6·42	12·07	66·81	2·06	2·25	0·45	2·04	1·93	6·76	11
310/1914	Maize grain, Mhow .	10·66	3·98	7·58	74·82	1·03	1·63	0·30	1·24	1·21	11·08	10
					Maize flour.							
621/1902	Maize flour (home made)	13·25	3·19	9·12*	71·61	1·29	1·54		1·46	..	8·66	10
					Green fodder.							
582/1900 L	Maize plant (fresh), Punjab	88·92	0·31	1·13	4·65	3·11	1·04	0·84	0·24	0·19	4·74	8
	Maize plant, dry state	10·04	2·52	9·17	37·76	25·25	8·44	6·82	1·95	1·51	4·75	67

ZINGIBER OFFICINALE, *Roscoe.*

English.—Ginger.

Vernacular.—Adi, Ada, Adrak, Sunt.

Laboratory No.	Description of Samples	% Moisture	% Ether extract	% Albuminoids	% Soluble carbohydrates	% Woody fibre	% Soluble mineral matter	% Sand and silica	% Total nitrogen	% Albuminoid nitrogen	Albuminoid nitrogen	Food units
54/1911	Ginger, Jamaica .	85·37	1·99	1·91*	8·12	1·00	1·61	0·00	0·31	..	6·65	17
55/1911	Do. Cochin .	87·38	1·63	1·59*	7·11	0·88	1·41	0·00	0·25	..	6·83	15
56/1911	Do. Calicut .	87·74	1·32	1·37*	7·28	0·92	1·37	0·00	0·22	..	7·53	14
57/1911	Do. Country .	85·47	1·46	1·80*	8·74	0·95	1·58	0·00	0·29	..	6·78	16

Water Hyacinth *(Eichornia crassipes)*

Its value as a fertilizer.

[*Received for publication on the 31st January, 1917.*]

IN recent years the growth of water weeds has increased to an alarming extent in the *bheels* [1] and *khals* [2] of the Dacca District of Bengal. There are two aquatic plants which are extremely common in this tract, *viz.*,—

(*a*) *Pistia Stratioites* (vernacular—Pana Gach) which has been known from time immemorial and which even now is showing no marked tendency to increase.

(*b*) Water Hyacinth ; *Eichornia crassipes*, Solms. ; vernacular—Kachuri, Tagoi, Belati pana in Bengal ; Bedaxbin in Burma.

The latter plant has been known in the neighbourhood of Calcutta for a number of years ; but it is said to have been introduced to Narayanganj, for ornamental purposes, only about five years ago. It is similar to *pana gach* in that both plants normally float on the surface of the water and possess abundant sub-aqueous roots ; but instead of the small size and flat-above-water appearance of *pana gach*, the hyacinth leaves stand out of the water to heights varying from six inches to over three feet.

We are indebted to Mr. H. G. Carter, Economic Botanist to the Botanical Survey of India, for the following technical description of water hyacinth :—

" *Eichornia crassipes*, Solms., belonging to the Family *PONTEDERACEŒ*, is a native of South America but has now become a troublesome weed in other countries, notably Florida, Java, Australia and India. The plant is a herb which multiplies extensively by division of the root-stock.

" When floating in water the plant has large bladder-like leaf-stalks which make it remarkably buoyant. The blade of the leaf acts as a sail, so that the plant, which multiplies very

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[1] The basin-like depressions which are known as *bheels* in North-Eastern India, *chars* or *tals* in Bihar, always hold water in the rains. Some are small and shallow and such as these probably dry up in the hot weather. On the other hand some *bheels* are very large, covering perhaps hundreds of square miles in the monsoon season and forming, even in the dry weather, permanent lakes of considerable size.

[2] In Deltaic Bengal numerous river channels are often connected by water courses, artificial or otherwise. These water courses, which are called *khals*, are practically the only means of communication over large tracts of country, especially during the monsoon.

rapidly, is carried about on the surface of the water and soon becomes a pest. When growing in mud the bladder like expansion of the leaf-stalk is absent. The plants bear spikes of ten or twelve handsome lilac flowers. The perianth is funnel-shaped and usually slightly irregular; it ends in six lobes. The six stamens are inserted on the perianth. The ovary is superior and three-celled and has axile placentation. The fruit is a loculicidal capsule containing seeds with abundant mealy endosperm."

The apparent resemblance of the flower of *Eichornia crassipes* to that of the Hyacinth (*Hyacinthus orientalis*, Liliaceæ) is responsible for its English title; but it will be seen from the above description that no botanical relation exists between these two plants.

The water hyacinth is solely responsible for the justifiable alarm which its rapid invasion of the water courses of the Dacca District is creating. Starting apparently from Narayanganj it may now be found in many distant low-lying parts of the Dacca District and it has already established itself in places as far away as Nattore and Gaibanda, which are across the Brahmaputra, in the Rajshahi and Rangpur Districts, respectively. In some *khals* near Narayanganj it has formed such a dense mass of vegetation as to render navigation impossible unless the hyacinth is removed, and it is therefore not to be wondered at that the Narayanganj Chamber of Commerce considered the matter sufficiently important to bring before the Governor of Bengal, Lord Carmichael, about two years ago (1914).

In the investigation, which was subsequently commenced, at the instance of His Excellency, it was discovered that *Eichornia* sp. is a serious pest, interfering with navigation in Burma, Indo-China, Australia and in Florida. In Madras it has been the subject of a note written by the Director of Agriculture; in Burma it has been described as one of the greatest administrative problems at present confronting Government and special legislation has been carried through with the object of eradicating it. In Indo-China elaborate investigations have been carried out with the object of finding an economic use for the very large quantities of organic matter which are to be disposed of; but, as in the case of "Sudd," a water weed which has caused such difficulties in the navigation of the upper reaches of the Nile, the investigations have apparently tended chiefly towards commercial exploitation of the weed, such as the manufacture of paper and the extraction of salts of ammonium. In Cambodia Professor Perrot proposes to use the fibrous matter of the plant for the manufacture of bags to replace jute gunnies now imported from India.

So far as our information goes, no commercially successful enterprise has, as yet, been based on water hyacinth : but apart from this, such schemes as the above seemed too elaborate in regard to the present state of affairs in India. Moreover, much valuable time would have been lost, firstly, over the necessary experiments and, in the event of their success, in proving to the commercial world the economic possibilities involved in the results. It was decided therefore, in the meantime, to approach the matter from an agricultural point of view and, as a preliminary step, specimens were chemically examined in regard to their content of agriculturally valuable material.

The present note deals with the results of the analyses and also includes an account of field experiments based on the analyses and carried out at Dacca in the last season (1916).

The original analyses were made on samples of plant obtained in Narayanganj, and samples of *pana gach* were also included for purposes of comparison. The results have subsequently been confirmed by examination of numerous samples taken from widely different sources. It appears that the various parts of the plants (leaves, stem and roots) differ somewhat in their constitution ; for instance a larger percentage of potash has been found in the stems and leaves than in the roots. The following may be taken as the approximate content of important constituents in the whole fresh green plant :—

TABLE I.

	Per cent.
Moisture	95·50
Organic matter	3·50
(containing Nitrogen)	0·04
Ash	1·00
(containing Potash)	0·20
Phosphoric acid	0·06

A typical analysis of the completely dried plant is as follows :—

TABLE II.

	Per cent.
Organic matter	75·8
(containing Nitrogen)	1·5
Ash	24·2

The ash contained the following :—

	Per cent.
Potash (K_2O)	28·7
Soda (Na_2O)	1·8
Lime (CaO)	12·8
Chlorine	21·0
Phosphoric acid (P_2O_5)	7·0

The ash was therefore equivalent to chloride of potash of practically 50 per cent. purity, in addition to containing considerable quantities of lime and phosphoric acid.

In the following table the important manurial constituents of *pana gach*, water hyacinth and various samples of farmyard manure are compared on a common basis of 65 per cent. moisture content.

TABLE III.

Heads	Nitrogen	Phosphoric acid (P_2O_5)	Potash (K_2O)	Organic matter
	Per cent.	Per cent.	Per cent.	Per cent.
(A) Young Pana Gach (*Pistia Stratioites*)	0·85	0·32	0·96	..
(B) Mature Pana Gach (*Pistia Stratioites*)	0·60	0·20	2·17	24·15
(C) Water Hyacinth (*Eichornia crassipes*), normal size	0·45	0·32	2·52	27·95
(D) Water Hyacinth (*Eichornia crassipes*), large size	0·60	0·23	2·61	27·95
(E) Cowdung (Leather) . . .	0·61	0·60	..	17·16
(F) Cowdung (Voelcker) . . .	0·56	0·20	0·50	25·56
(G) Cowdung (Voelcker) . . .	0·45	0·23	0·25	26·00
(H) Cowdung of grazing cattle (Leather)	0·39	0·26	..	21·42
(I) Cowdung (Dumraon), (Leather) .	0·34	0·20	..	12·63

An examination of the above figures (Table III) shews that the characteristic feature of both the water hyacinth and *pana* is their high content of potash, which has been found to compose as much as 35 per cent. of the ash of some samples of the former. Rotted water hyacinth is approximately five times as rich in potash as farmyard manure containing a similar percentage of water. In one case as much as 0·3 per cent. of potash was found in fresh green plant, a specimen kindly procured, in the monsoon season, by Mr. Hely-Hutchinson of Narayanganj, from the centre of a large *bheel.*

It would seem therefore that the water hyacinth exercises a selective absorptive power for potash, as a source of which it is, on this account of considerable value.

Water hyacinth is apparently not as rich in potash as the best marine sources of Kelp. For instance, Hendrick (*The Journal of the Society of Chemical Industry*, volume XXXV, page 567) gives roughly 28 per cent. as the average total ash content of the dry matter of *Laminaria digitata* (stems and fronds). For *Fucus* the average total ash content in the dry matter is about 20 per cent., and the corresponding figure for dried hyacinth also approaches 20 per cent. On the other hand the percentage (K_2O) content of hyacinth ash (average about 25 per cent.) appears to be nearly equal to that of *Laminaria* (26 per cent.) and decidedly higher than *Fucus* (15 per cent.). Of course the Kelp also contains iodine, which is a valuable constituent, but the respective problems involved in the use of seaweed and of water hyacinth, either as organic manures or for the production of ash, are not dissimilar.

The high potash content of these weeds is of considerable importance in North-Eastern India where the soils of the old alluvium are, on account of the leaching effect of the heavy rainfall, generally deficient in lime, potash and phosphoric acid. This is especially the case in the two extensive laterite areas, *viz.*, the Madhupur jungle in Eastern Bengal (Dacca, Mymensingh and Tippera Districts), the Bahrind (Rajshahi, Bogra and Dinajpur) in Western Bengal and, probably also, in other large areas in Assam.

Returning to Table III the analytical figures indicate that, apart from its high potash content, water hyacinth is at least as rich as farmyard manure of the same water content in both nitrogen and phosphoric acid.

In the case of the rotted hyacinth used in the field experiments in 1916, the nitrogen content of the dry rotted material was as high as 2·24 per cent. and in the damp state (containing 67·8 per cent. of water) 0·72 per cent.

Field Experiments.

In order to put the analytical results to a practical test, a set of field experiments was designed with this object in view. In the previous year (1915) application of the carbonates of soda and potash had produced very marked increases in the yield of jute, and it was therefore decided to use jute as the test crop.

The hyacinth was applied both in the rotted state and, after burning, as ash. With the help of Mr. S. G. Hart, I.C.S., Collector of Dacca, and of the Dacca Municipality we were able to collect about 850 maunds (roughly 30 tons) of the fresh green plant from the *khals* in Dacca City and cart it to the Dacca Farm. Of this about 499 maunds was heaped and allowed to rot while the remainder (351 maunds) was spread out to dry and afterwards burnt. Owing to the very high water content the rotting

of the fresh green plant involved a considerable loss, in the form of liquid which was squeezed out in large quantities, during the decomposition process. That this loss was serious is shewn by the fact that while the rotted residue from practically 500 maunds of green plant was only sufficient to manure four plots (0·4 acre) at the rate of 78 lb. potash (K_2O) per acre, the ash from 351 maunds of green plant was sufficient to apply to 11 plots at the rate of 94 lb. per acre of potash (K_2O). In other words, by drying and burning the plant, the ash obtained from 300 maunds of green plant gave a larger quantity of potash than was obtained from 1,000 maunds of similar plant after rotting.

The actual details are as follows :—

	Mds.	Srs.
Rotted Hyacinth—		
Weight of fresh green hyacinth before rotting . (*N.B.*—One maund=40 srs. =82 lb.)	498	31
Weight of residue after rotting . . .	16	20
i.e., weight of rotted residue per 100 mds. of green plant	3	13
Approximate potash content of residue . .	2·5 per cent. K_2O	
Therefore total potash in rotted residue from 100 mds. (8,200 lb.) green plant . .	$\frac{266}{100} \times 2{\cdot}5 = 6{\cdot}65$ lb. K_2O	

	Mds.	Srs.
Hyacinth ash—		
Weight of fresh green hyacinth taken . .	356	39
Weight of ash after drying and burning . .	5	14½
Weight of ash per 100 mds. of green plant. .	1	20
Approximate potash content of ash . .	25 per cent. (K_2O)	
Therefore total potash in ash residue from 100 mds. green plant	30·5 lb. (K_2O)	

It would thus appear that the rotting process, as carried out, involved a loss of something like 70 per cent. of the available potash, and 60 per cent. of the nitrogen was also carried away. In the present season this loss is being avoided, for experimental purposes, by partly drying the plant before stacking and also, in another case, by mixing dried plant with fresh plant in the heap. Under ordinary circumstances of course earth, dry refuse or jungle would be equally useful.

Of the four plots manured with rotted hyacinth, two duplicates received lime at the rate of 20 maunds (1,640 lb.) per acre and the remaining two—also duplicates—were not limed. It was at first intended to apply the rotted material at the rate of 40 lb. of nitrogen per acre, so as to compare with the 40 lb. of nitrogen in the castor cake which the check plots received ; but through an error in calculation, only half this amount, *i.e.*, 20 lb. of nitrogen per acre was put on. This was

fortunate as it served eventually to accentuate the value of the potash, about 78 lb. per acre of which was contained in the rotted material actually applied. The potash in the castor cake was only about 8 lb. per acre.

The hyacinth ash was applied on the basis of its potash content at the rate of 94 lb. (K_2O) per acre.

As a check on the plots to which ash was applied, other plots were respectively given equivalent amounts of potash, in the form of sulphate of potash, with and without lime; carbonate of potash, with and without lime, and chloride of potash, with lime. In addition other plots received a mixture of sulphate and chloride of potash, with lime. To another set of plots carbonate of soda was applied, with and without lime, at the rate of 62 lb. per acre of Na_2O which is equivalent to 94 lb. per acre of K_2O; and to still another set a mixture of the carbonates of soda and potash with and without lime was applied at the rates of 22·5 lb. Na_2CO_3 and 110 lb. K_2CO_3 per acre, these being the approximate respective proportions of soda to potash in the hyacinth ash.

All the plots to which only salts were applied received castor cake in addition at the rate of 40 lb. nitrogen per acre.

The rotted *pana gach* was applied, with and without lime, at the rate of 40 lb. nitrogen per acre.

The land was typical of the Dacca Farm, and of the laterite tract in general, in that it is very uneven indeed and so it was necessary to include a very large number of checks. Out of a total 72 plots there were 22 checks and it was arranged that every plot should be adjacent to at least one check; in most cases as will be seen in the sequel, the mean of two or more checks has been taken. The results obtained are of course only approximations; but the margins over the checks are in nearly every case so large as to leave no doubt regarding the positive effect of hyacinth, both in the rotted state and in the form of ash. The fact that the rotted hyacinth plots received only half as much nitrogen as the checks, and yet gave higher yields, shews that the potash was the active constituent. This result is supported by the increased yields on the plots which received hyacinth ash, and on those to which salts of potash were applied; entirely similar results were also obtained in the previous year (1915) by application of potash to other plots.

The manurial history of the field is as follows :—

1912	30 mds. (2,460 lb.) slaked lime per acre.
1914	3 mds. (246 lb.) bonemeal per acre.

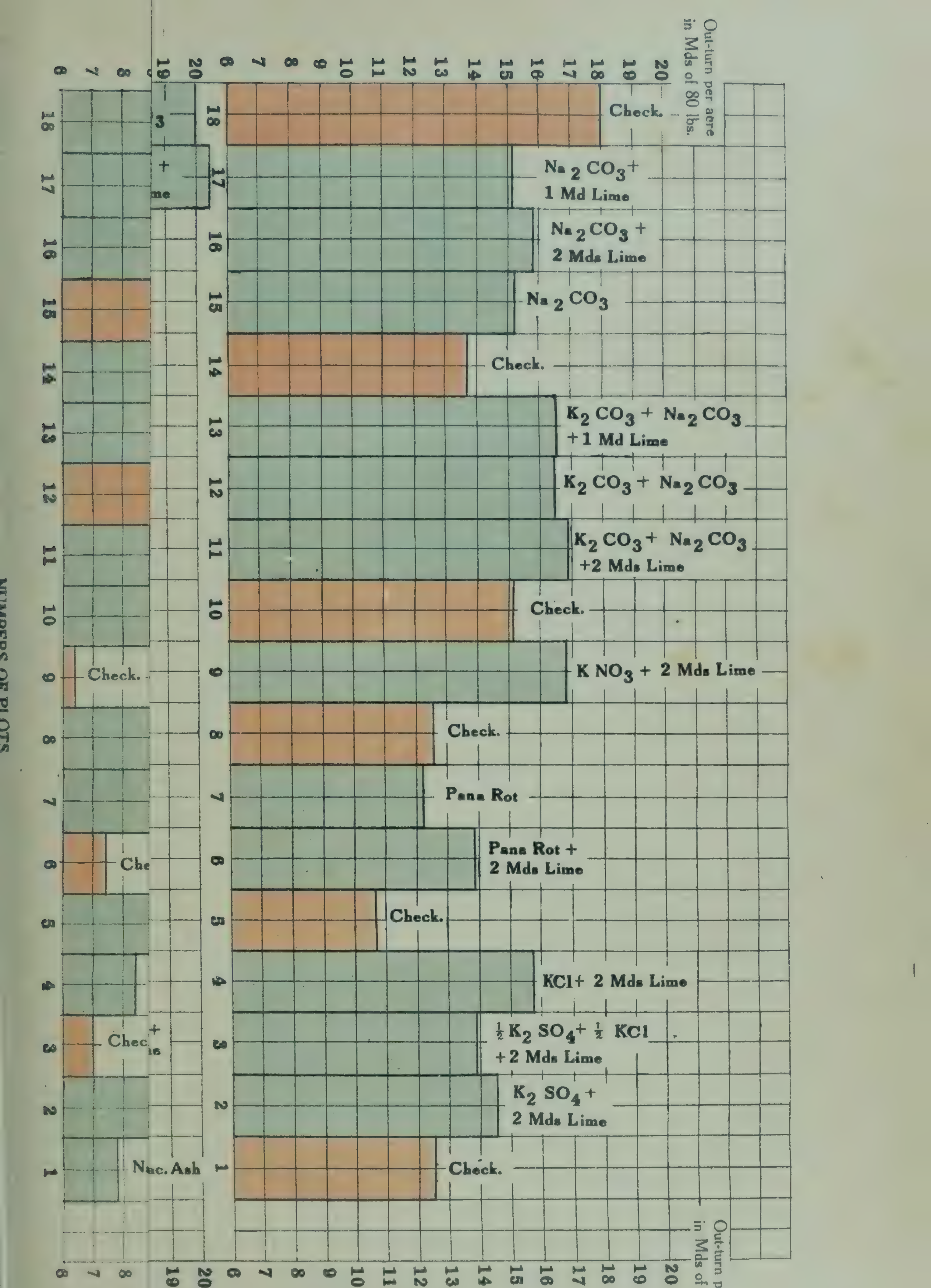
The season 1916 was unfavourable for jute in the laterite tracts.

After an early fall in February there was no more rain until the first week of April, after which there was constant wet weather for a fortnight. Sowing took place on the 23rd April after which, with the exception of showers early in May, there was no more rain until the second week in June. July brought another prolonged drought.

Results of the experiments.

Details of the yields of the various plots are given below (*N.B.*, 1 maund=40 seers=82 lb.). The yield of fibre per acre from each plot is also marked to scale on the attached plan of the field which, in addition, affords a bird's-eye-view of the arrangement of the plots :—

Number of plot	Yield per acre	Numbers of check plots	Yields of check plots	Mean of checks	Difference between experiment and mean of checks	Mean of duplicate differences per acre
	m. s.		m. s.	m. s.	m. s.	m. s.
		Rotted hyacinth without lime.				
5 b	13 33	4 b	9 36	8 22	5 11	5 8
		7 b	6 27			
		5 a	10 27			
		5 c	6 36			
12 c	15 0	11 c	8 36	9 34	5 6	
		14 c	7 11			
		12 b	12 10			
		12 d	11 2			
		Rotted hyacinth *plus* lime (20 mds. per acre).				
6 b	14 23	..	..	8 22	6 0	6 32
13 c	17 17	..	..	9 34	7 23	
		Rotted *pana gach* without lime.				
7 a	12 13	5 a	10 28	11 28	0 23	1 6
		8 a	12 29			
14 d	12 5	15 d	10 10	10 26	1 19	
		12 d	11 2			



Out-turn per acre in Mds of 80 lbs.
Check.
Na_2CO_3 + 1 Md Lime
Na_2CO_3 + 2 Mds Lime
Na_2CO_3
Check.
$K_2CO_3 + Na_2CO_3$ + 1 Md Lime
$K_2CO_3 + Na_2CO_3$
$K_2CO_3 + Na_2CO_3$ +2 Mds Lime
Check.
K NO_3 + 2 Mds Lime
Check.
Pana Rot
Pana Rot + 2 Mds Lime
Check.
KCl+ 2 Mds Lime
$\frac{1}{2} K_2SO_4 + \frac{1}{2}$ KCl +2 Mds Lime
K_2SO_4 + 2 Mds Lime
Check.
Nac. Ash
Check.
NUMBERS OF PLOTS
Out-turn per acre in Mds of 80 lbs.

BLOCK A

Number of plot	Yield per acre	Numbers of check plots	Yields of check plots	Mean of checks	Difference between experiment and mean of checks	Mean of duplicate differences per acre
	m. s.		m. s.	m. s.	m. s.	m. s
Rotted *pana gach plus* lime (20 mds. per acre).						
6 a	13 35	..	..	11 28	2 7	2 21
13 d	13 18	..	..	10 26	2 34	
Hyacinth ash without lime.						
1 b	17 22	1 a	12 23	12 23	4 39	5 33
15 c	16 33	18 c	11 16	10 7	6 26	
		14 c	7 14			
		15 b	11 31			
Hyacinth ash with lime (10 mds. per acre).						
2 b	13 38	1 c	9 9	9 22	4 16	5 21
		4 b	9 36			
17 c	16 33	..	..	10 7	6 26	
Hyacinth ash with lime (20 mds. per acre).						
3 b	15 9	4 b	9 36	..	5 13	6 3
16 c	16 31	..	..	10 7	6 24	
Carbonate of potash without lime.						
18 b	20 0	18 c	11 16	14 28	5 12	4 35
		18 a	18 0			
4 c	11 14	5 c	6 36	..	4 18	
Carbonate of potash *plus* lime (10 mds. per acre).						
17 b	20 23	..	..	14 28	5 35	5 27
2 c	14 26	1 c	9 9	..	5 19	
Carbonate of potash *plus* lime (20 mds. per acre).						
16 b	17 8	15 b	11 31	..	5 17	6 4
3 c	14 34	1 c	9 9	8 3	6 31	
		5 c	6 36			

Number of plot	Yield per acre	Numbers of check plots	Yields of check plots	Mean of checks	Difference between experiment and mean of checks	Mean of duplicate differences per acre
	m. s.		m. s.	m. s.	m. s.	m. s.
Mixed carbonates of soda and potash without lime.						
12 a	16 13	10 a	15 5	14 18	1 35	2 26
		14 a	13 31			
5 d	10 14	3 d	7 0	6 38	3 16	
		6 d	7 16			
		9 d	6 16			
Mixed carbonates of soda and potash *plus* lime (10 mds. per acre).						
13 a	16 20	..	..	14 18	2 2	3 2
7 d	11 0	..	..	6 38	4 2	
Mixed carbonates of soda and potash *plus* lime (20 mds. per acre).						
11 a	16 35	..	..	14 18	2 17	3 25
8 d	11 32	..	..	6 38	4 34	
Carbonate of soda without lime.						
15 a	15 6	14 a	13 31	..	1 15	1 0
1 d	7 26	3 d	7 0	..	0 26	
Carbonate of soda *plus* lime (10 mds. per acre).						
17 a	15 6	14 a	13 31	..	1 15	1 16
4 d	8 18	3 d	7 0	..	1 18	
Carbonate of soda *plus* lime (20 mds. per acre).						
16 a	15 32	14 a	13 31	..	2 1	3 15
2 d	11 30	3 d	7 0	..	4 30	
Sulphate of potash without lime.						
11 b	12 25	12 b	12 0	10 5	2 20	2 30
		9 b	9 8			
		11 c	8 36			
10 c	12 1	11 c	8 36	9 2	2 39	
		8 c	9 8			

Number of plot	Yield per acre	Numbers of check plots	Yields of check plots	Mean of checks	Difference between experiment and mean of checks	Mean of duplicate differences per acre
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
Sulphate of potash *plus* lime (20 mds. per acre).						
2 a	14 24	1 a	12 22			
		5 a	10 28	11 2	3 22	
		4 b	9 36			
18 d	16 10	18 c	11 16	..	4 34	3 17
10 b	13 3	..	..	10 5	2 38	
9 c	11 15	..	..	9 2	2 13	
Mixed sulphate and chloride of potash *plus* lime (20 mds. per acre).						
3 a	13 34	..	..	11 2	2 32	
17 d	17 10	18 c	11 16			4 24
		15 d	10 10	10 33	6 17	
Chloride of potash *plus* lime (20 mds. per acre).						
4 a	15 31	..	..	11 2	4 29	
16 d	18 28	..	..	10 33	7 35	6 12
Nitrate of potash { 28 lb. nitrogen per acre; 77 lb. potash per acre } applied in three top-dressings. Castor cake . . . . 12 lb. nitrogen per acre. Lime . . . . . 20 maunds per acre.						
9 a	16 35	8 a	12 19	13 32	3 3	
		10 a	15 5			
10 d	8 36	9 d	6 16			2 32
		12 d	..	..	2 20	
Nitrate of potash, Castor cake } as above (without lime).						
8 b	11 16	9 b	9 8	..	2 8	
11 d	8 35	12 d	11 2			1 7
		9 d	6 16	8 29	0 6	

Number of plot	Yield per acre	Numbers of check plots	Yields of check plots	Mean of checks	Difference between experiment and mean of checks	Mean of duplicate differences per acre
	m. s.		m. s.	m. s.	m. s.	m. s.
Nitrate of potash top-dressing of 48 lb. (KNO_3) per acre, 4·7 lb. nitrogen per acre.						
13 b	12 35	12 b	12 10	12 0	0 35	1 4
		15 b	11 31			
6 c	9 15	5 c	6 36	8 2	1 13	
		9 c	9 8			
Nitrate of soda top-dressing of 40 lb. ($NaNO_3$) per acre, 4·0 lb. nitrogen per acre.						
14 b	11 8	..	..	12 0	−0 35	..
7 c	8 7	..	..	8 2	+0 5	

Discussion of the results.

It has already been pointed out that potash is the characteristic constituent of water hyacinth: it has also been mentioned that extraordinary results were obtained with potash on jute in the season 1915, when the addition of carbonate of potash to an otherwise complete manure of castor cake, phosphates and lime, produced the phenomenal yield, on duplicate plots, of nearly 34 mds. of fibre per acre. Duplicate check plots which did not receive potash, but which were otherwise similarly treated, produced less than 27 maunds per acre. There was therefore a margin of over 7 maunds per acre in favour of the potash. In view of this it was to be expected that any effect produced by the hyacinth, either in the rotted state or as ash, would be due to its potash and the results of the experiments entirely confirm this idea: further support is also afforded by the enhanced yields obtained from the plots which received potash in the respective forms of carbonate, chloride and sulphate, especially the two former. The effect of the chloride of potash, as contrasted with that of sulphate of potash, is interesting in view of the fact, already mentioned, that a high percentage of chlorine was found in the hyacinth and that the hyacinth ash contained nearly 50 per cent. of chloride of potash.

In other experiments with jute on laterite soils at Dacca it has been found that an application of 30 maunds of lime (approximately

1 ton) per acre results in an increased yield of 4 maunds of fibre per acre ; moreover the effect of the lime lasts for at least three years.

The land on which this year's (1916) experiments were carried out received 30 maunds of lime per acre in 1912 and it is probably due to this that the effect of the lime applied in 1916, though favourable, is comparatively slight.

The *pana gach* used in the experiments was mixed with a large proportion of earth : it was collected from a place where, the floods having receded early, the *pana* had taken root where it was deposited.

The potash content in its ash was only 2·7 per cent. as against 26 per cent. for hyacinth.

It is perhaps advisable, before concluding this note, to again point out that about 95 per cent. of the weight of fresh green hyacinth consists of water ; it would not therefore be an economic proposition to transport the green plant over any considerable distance.

The well-rotted residue would probably contain from 50 per cent. to 60 per cent. of water ; in this state it would be comparable with farm-yard manure, excepting that the hyacinth residue is much richer in potash.

It is also worth remembering that if the fresh green plant be immediately stacked for rotting, a very serious loss of valuable material takes place in the liquid exuded during the rotting process. To prevent this, either the whole of the plant should be dried for a few days before stacking, or the fresh plant may be stacked in alternate layers with dried plant : a similar result would be obtained by mixing the fresh plant with earth or with dried weeds or jungle.

The well-dried plant is only about one-twentieth of the original green weight. It is therefore in a much more convenient state for transport than either the fresh plant or the rotted material. Its weight, per unit of mineral plant food, is about five times that of the ash, of which it contains from 20—25 per cent., including about 8 per cent. of potash (K_2O).

Its bulk is considerable ; but on the other hand it contains organic matter and from 1·5 per cent. to 2 per cent. of nitrogen, both of which are lost on burning.

The ash of the hyacinth is of course the most convenient form to reduce the plant to if transport is the object. It only forms about 1 per cent. by weight of the original green plant, whereas the dried plant is five times heavier ; but in reducing its bulk by burning the dried plant all the nitrogen and organic matter are lost. Nevertheless the whole of the mineral constituents are recovered in an easily available form.

Messrs. Shaw, Wallace & Co. of Calcutta have offered to buy hyacinth ash on the terms described in the following letter :—

4, BANKSHALL STREET, CALCUTTA.
The 12th August, 1916.

To

The Fibre Expert to the Government of Bengal,
C/o The Director of Agriculture,
Writers' Buildings, Calcutta.

SIR,

With reference to the interview of our Mr. Arnold with the Acting Director of Agriculture, Mr. McLean, and yourself on the subject of the ash of the water hyacinth, we are prepared to consider the purchase of the whole of the ash produced from the water hyacinth in India and Burma. We understand that in the first instance, the details of collection of the weed will be carried on by a local contractor, or contractors, when you find suitable responsible men.

The present price which we can offer you is Rs. 4 per full unit of potash f.o.r. or f.o.b. Calcutta. If the ash reached us in good condition and is not adulterated we estimate that it will work out at a minimum price of Rs. 84 per ton. Based on your analysis, it would be Rs. 112. Our procedure would be to make one analysis of each delivery of 5 tons of ash, and pay on the basis of that analysis.

We should esteem it very much if you will make it known among the agriculturists and those who can promote the scheme and we hope to hear from you how the matter is received by them, and later on what progress is being made. To make the collection of potash in this way successful, we would point out that the present time is most favourable, as other sources of potash are temporarily restricted.

Should the matter be taken up seriously, we would like to know what shipments we may expect and the date on which they will begin.

We have the honour to be,
SIR,
Your most obedient servants,
SHAW, WALLACE & CO.

Summary.

(1) The analytical figures detailed above indicate that, in Bengal, water hyacinth (*Eichornia crassipes*) contains considerable stores of valuable plant food of which potash is the chief constituent. If rotted the residue contains about the same amounts of nitrogen and phosphoric acid as, perhaps rather more than, ordinary farmyard manure ; and it is several times as rich in potash.

(2) The fresh green plant contains about 95 per cent. of water and could not be economically transported over any great distance. The rotted plant, containing about 60 per cent. of water, is comparable with cowdung in this respect, and it is likely therefore that the use of the

rotted material will be confined to the immediate neighbourhood of its production.

(3) The dried material is only about one-twentieth of the weight of the green plant: and is thus in a much more convenient form for transport than either the green plant or the rotted material. It contains from 1·5—2 per cent. of nitrogen and about 8 per cent. of potash (K_2O).

(4) After burning, the ash residue of clean water hyacinth (unmixed with earth) has been found to contain as much as 35 per cent. of potash (K_2O) and an average figure for the Dacca District would seem to be over 25 per cent. The ash is therefore several times richer in potash than ordinary wood ashes.

(5) Messrs. Shaw, Wallace & Co. of Calcutta have offered to purchase any quantity of hyacinth ash on the terms detailed in their letter quoted above, *viz.*, Rs. 4 per unit of potash landed in Calcutta. This corresponds to from about Rs. 84 to Rs. 120 per ton.

(6) The results of the field tests, detailed herein, shew conclusively that water hyacinth is a valuable manure, either in the rotted state, or as ash, on laterite soils of the old alluvium in Bengal. Some of the various types of silt which compose the new alluvial tracts also exhibit, in a modified degree, the deficiency in potash, phosphoric acid and lime which is characteristic of the red soils of North-Eastern India, and there is little doubt that hyacinth either rotted or as ash, will prove an equally valuable manure for them. A good deal of evidence to this effect is already available. On the high, light, well-drained soils the rotted material might be preferable; but on heavy low-lying lands the ash would probably be more successful.

(7) Two hundred Presidents of Panchayets in the Dacca District were brought to the Dacca Farm in August 1916 by Mr. Hart, Collector of Dacca, and were shewn the jute crop on the experimental plots which had been manured with hyacinth.

(8) In consultation with Mr. Hart, leaflets in English and Bengali have been drawn up containing information regarding the uses to which the water hyacinth can be put: 10,000 leaflets in Bengali and 1,000 in English have recently been distributed in the Dacca District by Mr. Hart.

(9) There are already indications that the cultivator is beginning to appreciate the agricultural possibilities of water hyacinth. As the knowledge spreads in a densely populated tract like Eastern Bengal, where moreover one of the staple crops like jute answers to heavy manuring there is a powerful incentive for the people to solve the problem for themselves, either individually or collectively, through village or co-operative agencies.

Much credit is due to Mr. N. C. Basu, M.Sc., and to Babu Tara Nath Ray, Chemical Assistant and Field Assistant, respectively, on the staff of the Fibre Expert, for careful work in connection with this investigation.

DACCA,
January 6, 1917.

The interval since the above note was written has afforded an opportunity of judging how far the suggestions put forward for the control of water hyacinth in Bengal are likely to be effective. In the first place a definite start has been made by the public in the conversion of the plant into ash, and the fact that about 170 tons (roughly 4,500 maunds) of ash have actually been sold in Calcutta and Dacca speaks for itself. These figures which take no account of ash which may have been made, and applied to land in the district where it was produced, represent the destruction of about 17,000 tons (four and a half lakhs of maunds) of the green plant.

It is hardly necessary to point out that the above quantities are only a very small fraction of the enormous total which has to be dealt with ; but it is also equally obvious that an encouraging start has now been made.

Further investigation has shown that the composition of the ash varies considerably with the conditions under which the plant grows. In the water courses in Dacca City the growth of the plant is very luxuriant, reaching as great an above-water-height as 3 feet. Such big plant has been found to contain the richest ash. On the other hand, the plant growing on land, or in shallow water, especially in the red soil districts, is usually stunted. It often contains a large percentage of ash, but the greater portion of this proves to be silica and the potash content is comparatively low. Analyses of the ash of tall plant from the Dacca *khal* and from a tank at Mirpur on the red soil are appended :—

	Plant from Dacca *khal*	Plant from Mirpur (red soil)
Ash in dried plant	30·6 per cent.	29·8 per cent.
containing SiO_2. . . .	20·72 ,,	49·43 ,,
K_2O. . . .	34·15 ,,	11·36 ,,
P_2O_5 . . .	8·20 ,,	1·41 ,,
CaO . . .	8·43 ,,	7·79 ,,
Cl	20·37 ,,	5·66 ,,

The ash of No. I would be worth Rs. 5 per maund (80 lb.) f. o. r. Calcutta, on the basis Rs. 4 per unit of potash. Moreover, its content of phosphoric acid adds roughly R. 1 per maund (80 lb.) to its value, making a total approximating to Rs. 6 per maund.

No. II has only one-third the potash content of No. I and is the poorest sample of clean plant ash yet examined. It is worth about Rs. 1-11-0 per maund.

It has been found that a considerable proportion of the potash in the dead hyacinth plant can be extracted with cold water. Therefore the preparation, either of ash or of rotted material, is to be avoided in Bengal during the rainy season. From the middle of October till the end of March would appear to be the most suitable time for these operations.

12th June, 1917.

R. S. F.
K. M.

CALCUTTA : PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8, HASTINGS STREET.

Fig. 1. Showing raw patch (A) and swelling (B).

Fig. 2. Showing raw patch (A).

A Note on Jhooling in Camels.

[*Received for publication on the 19th February, 1917.*]

Jhooling, or Jhoolak as the disease is sometimes called, is a contagious disease of camels—manifesting itself in the formation of local tumours, hot and painful, of a fibrous character and terminating in suppuration and raw patches.

Distribution. The disease is widely distributed throughout the Punjab ; it is not so common in the Lahore District as in the Jhelum and Rawalpindi Districts. It usually occurs in the cold weather but is met with occasionally in the hot weather.

Etiology. The causal organism has not yet been isolated though it is probably a fungus.

Pathogenicity. Inoculation of emulsion of the lesion into horses, cattle, buffaloes, dogs, guinea-pigs and rabbits does not produce the disease.

If portions of the lesion are rubbed on the skin, whether the skin be scarified or not, no Jhooling lesion is produced in any of the above animals.

Horses, buffaloes, and cattle kept in contact with camels suffering from Jhooling do not contract the disease.

When portions of a Jhooling lesion are rubbed on the scarified skin of healthy camels the disease develops after a few days. In only one case did the disease develop when a portion of a Jhooling lesion was rubbed on the unscarified skin of healthy camels.

Healthy camels kept in contact with camels suffering from Jhooling contract the disease rapidly.

Symptoms. The first symptom is a hot, hard and painful swelling varying from 1 to 5 inches in diameter, usually on the neck, hindquarters or testicle, but the lesions may occur in almost any part of the body. After a few days the swelling becomes very irritating, and, if situated in any part of the body that the camel can reach with his teeth, he will gnaw at it leaving a raw patch. In all cases after the lapse of some time suppuration takes place and finally the wound heals, leaving a small white patch which lasts for several months. As a rule several lesions are found on a camel suffering from the disease and the camel loses condition. The lesions take a long time to heal and if situated in any part that comes in contact with the *palan* (saddle) the camel has to be put off work.

Anatomical changes. The tumour consists of fibrous tissue finally undergoing suppuration. Examination of the pus reveals streptococci : no staphylococci have been observed. In camels suffering from Jhooling, on which I have made post-mortems, no lesions have been observed in the internal organs.

Treatment 1. The best treatment and one which gives very satisfactory results, is the following :—A strong red iodide of mercury blister should be applied, and after three days washed off with soap and water. The diseased areas should then be excised and finely powdered permanganate of potash applied. The permanganate of potash must be well rubbed in and not simply dusted on. Three dressings at intervals of four days are usually sufficient.

Treatment 2. Sometimes good results are obtained by excising the lesion and then applying pure phenyle or carbolic acid. The following day the wounds should be thoroughly washed with water and then treated with Black wash (30 grains calomel, half an ounce of glycerin, $1\frac{1}{4}$ ounces of tragacanth mucilage and lime water to make 10 ounces of lotion).

Camelmen apply boiling ghee to the lesions and " fire " round the edges of the lesions with the idea of preventing the lesion spreading. This treatment cannot, however, be considered satisfactory.

If the lesions are on the testicle, or in situations where they can be reached by the tail, the tail must be tied.

Prevention. Camelmen are well aware of the contagious nature of this disease. If they have a camel suffering from Jhooling lesions in the neck this camel is always placed first in the string of camels ; whereas if the lesions are on the hindquarters the camel is tied last.

Should a case of Jhooling occur amongst a number of camels, it should be at once isolated from all the other camels. The remaining camels should be very carefully examined and divided up into lots and not allowed to mix. Should more cases be found they should be at once isolated. The disease spreads very rapidly amongst camels and causes a great deal of trouble, so that every effort should be made to prevent the disease from spreading, by careful examination and segregation. In camels suffering from Jhooling, lesions in different stages are met with—healed up lesions, raw patches and swellings.

No camel should be bought if small hard white spots are observed on the skin (they undoubtedly represent healed up Jhooling lesions) without careful inspection for raw patches and swellings.

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Fig. 1. Showing healed lesion (A) and partially healed lesion (B).

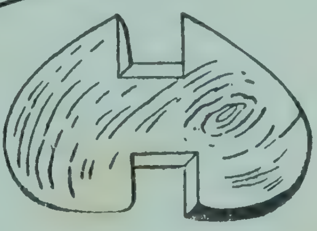
Fig. 2. Showing healed lesions.

New Agricultural Implements for India.

[*Received for publication on the 4th April, 1917.*]

THE following implements were introduced at various times by the writer and used in Sind. They are mostly modifications of implements in common use in Egyptian Agriculture and are likely to be most useful in irrigated districts. All have been thoroughly tested and are thoroughly practical.

I. Plough.



Ridging Attachment.

This has " caught on " very well in some parts of Sind and is ousting the native plough which is little more than an iron spike fixed to the end of a pole.

The above plough is like the indigenous wooden plough of Egypt. When the land can be softened by water it is an efficient implement and is specially useful in small plots and in rough ground containing tree stumps and roots. It is really a 1-toothed cultivator and holds its own in the estimation of the " fellah " against repeated attempts to introduce iron ploughs. Plate I)

Construction. The pole is made of jarrah or any long grained wood and should be about 11 feet long and 4 inches broad and 2½ inches thick. The body is of babul wood about 3 feet 6 inches long. The body and pole are dovetailed into each other and fastened by a movable bolt. The handle is fastened to both ends of the body, leaving the pole free to move on removal of bolt. Half-way along the body an iron bar is fastened through the body, and goes through the pole. At the top of the iron are several holes by means of which the angle between body and pole can be regulated. The share is 6½ inches broad and spear-shaped, being fastened to end of the body. The total cost of construction, including labour and material, is between Rs. 5 and Rs. 6, depending on price of wood.

Hardened steel shares were imported from England before the war at R. 1 each. These increased the life of the plough considerably.

Ridging. For ridging up land a piece of wood as shown in diagram is inserted in front of the iron bar. The cost of ridging with the plough is very considerably cheaper than the same work done by hand with the "kodar." With a couple of ploughings, land will generally be in sufficiently good tilth for ridging up. This is essential for the proper growth of Egyptian cotton; also useful, among other crops, for potatoes. This plough has an advantage over an English plough in that the cultivator takes to it naturally. He has no difficulty in holding it, as he has with some of the two-handled iron ploughs.

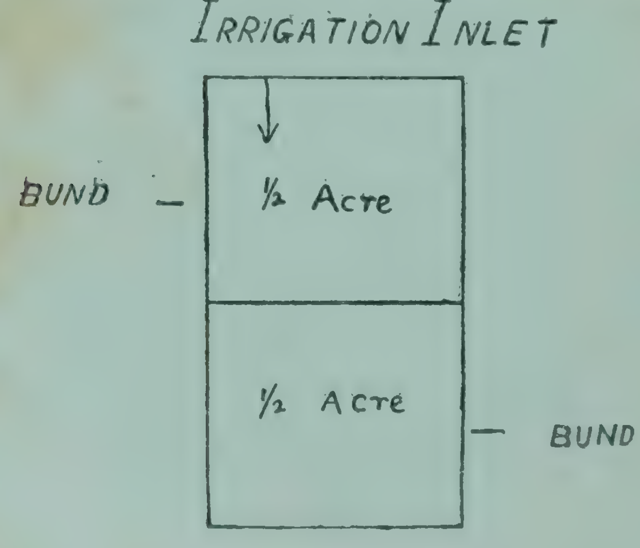
II. The "Gassibiah" or Scraper for levelling land.

This implement is specially important on irrigated land. On an irrigation canal, in particular, it is essential that the fields should be quite level, otherwise it is impossible to give a uniform watering to any crop. Watering unlevel ground is not only a very common source of much waste of water but is also injurious to the crops and is apt to favour the accumulation of "kalar" or alkali at one end of the field. It is not an uncommon sight to see crops in Sind being watered 10 to 12 inches deep at one end of a field and dry at the other.

On the other hand, dividing up the land according to its natural level into small irregular patches is exceedingly wasteful both of land and water.

If, however, the land were divided into rectangular plots and properly levelled to begin with, the result would be much more satisfactory.

It is good practice to level new ground into rectangular 1-acre plots and to make bunds with the scraper all round and one bund across the



PLOUGH.

PLATE II.

SCRAPER FILLING.

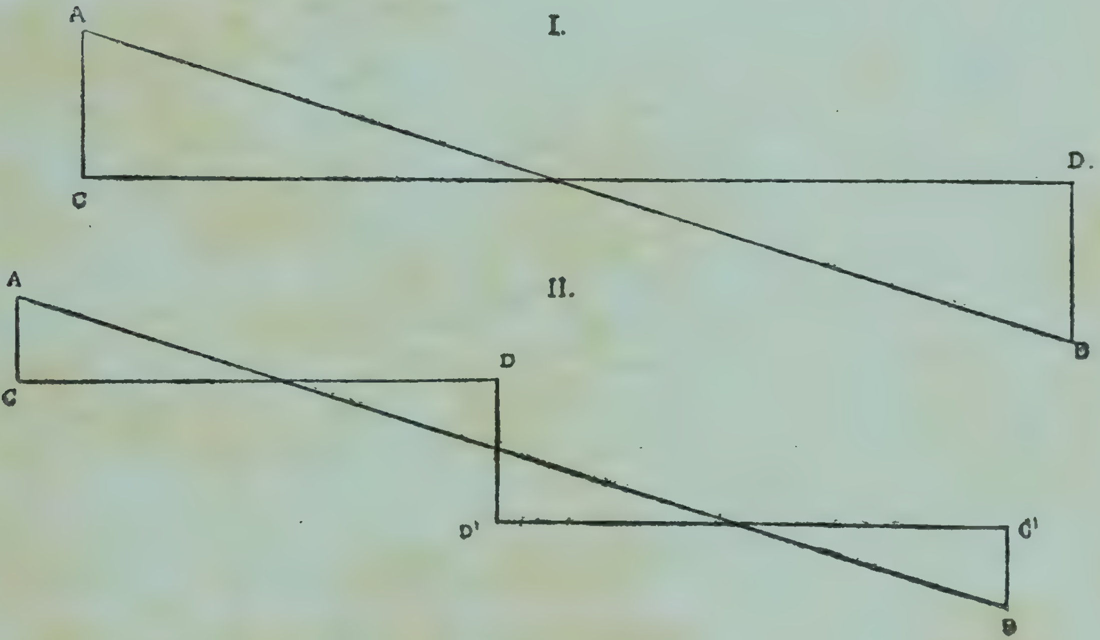
SCRAPER RETURNING EMPTY.

middle. These bunds are permanent and so save the expense of renewing for every crop, and are much less likely to break with the consequent wastage of water.

On non-irrigated land also there are many places where levelling can be done to prevent erosion where the rainfall is great and also to fill bad hollows.

At Pusa it took 5 scrapers, and 2 ploughs working in front of them, 45 days to level 17 acres of very uneven rice land, *i.e.*, 5 scrapers and 2 ploughs did one acre in between 2-3 days. (*See* Frontispiece.)

In irrigated land levelling is a most expensive operation, and unnecessary levelling means much extra expense. More money can be wasted in levelling than in any other agricultural operation. It is not advisable to have adjacent land at very different levels as damage may be done by infiltration. In a plot however that does not vary more than a foot, it is advisable to put up a central bund and level each part separately, *e.g.*:



If A-B represents level of original plot levelled to C-D and in II levelled to C-D and C′-D′ then in levelling I there is double the quantity of earth moved double the distance compared to II, *i.e.*, four times the cost.

In Sind it was found that letting water into a 50 × 150 yards plot at one end tended to accumulate alkali at the far end; so all the plots were divided by a central bund, the top portions being watered by a special "add" (water channel) and so fresh water was put on directly to each 75 × 50 yards portion, net $\frac{3}{4}$ of an acre.

Construction. The scraper is a box-shaped arrangement, the sides being 2 feet long and 9 inches high, and these are continued into handles 3 feet long, the ends being 2 feet from the ground. At this point they are 1 foot 8 inches apart and at the gathering edge $2\frac{1}{2}$ feet. The bottom is convex and is formed of strips of wood nailed to the sides and protected with sheet iron strips. The gathering edge is of iron 4 inches wide. The illustrations (Plates II and III) clearly show its construction and working. When filled with earth, it is simply tipped over and the soil may either be spread out gradually or put in one place to make a bund. A rope is fixed across the handle which rests on the draft chain when returning empty. The scraper can also be used for grading roads or making embankments. The price is Rs. 7.

III. The "Norag" or Threshing Machine.

This implement (Plate IV) is a valuable one where power threshing machines are not used. Though primarily intended for wheat, it will thoroughly thresh gram, *mutter* (*P. arvense*), rice, *jowar* (*Sorghum vulgare*) and *bajri* (*Pennisetum typhoideum*). It leaves the straw cut up in suitable condition for feeding. The country system of threshing by tying a number of cattle together and making them walk round in a circle is a slow and most primitive method.

This machine, called in Egypt the "Norag," consists of 3 axles, on each of which are fixed six to seven iron discs. The axles revolve in iron bearings, and the whole rests in an angle iron frame. The machine is pulled by one pair of bullocks and will thresh as much as five to six pairs of bullocks would tread out.

The discs are kept sharp by the occasional use of the file. Beyond this the machine needs no attention, as the whole thing is strong and practically indestructible.

The iron discs are $1\frac{1}{2}$ feet in diameter, and the price of the machine is about Rs. 40.

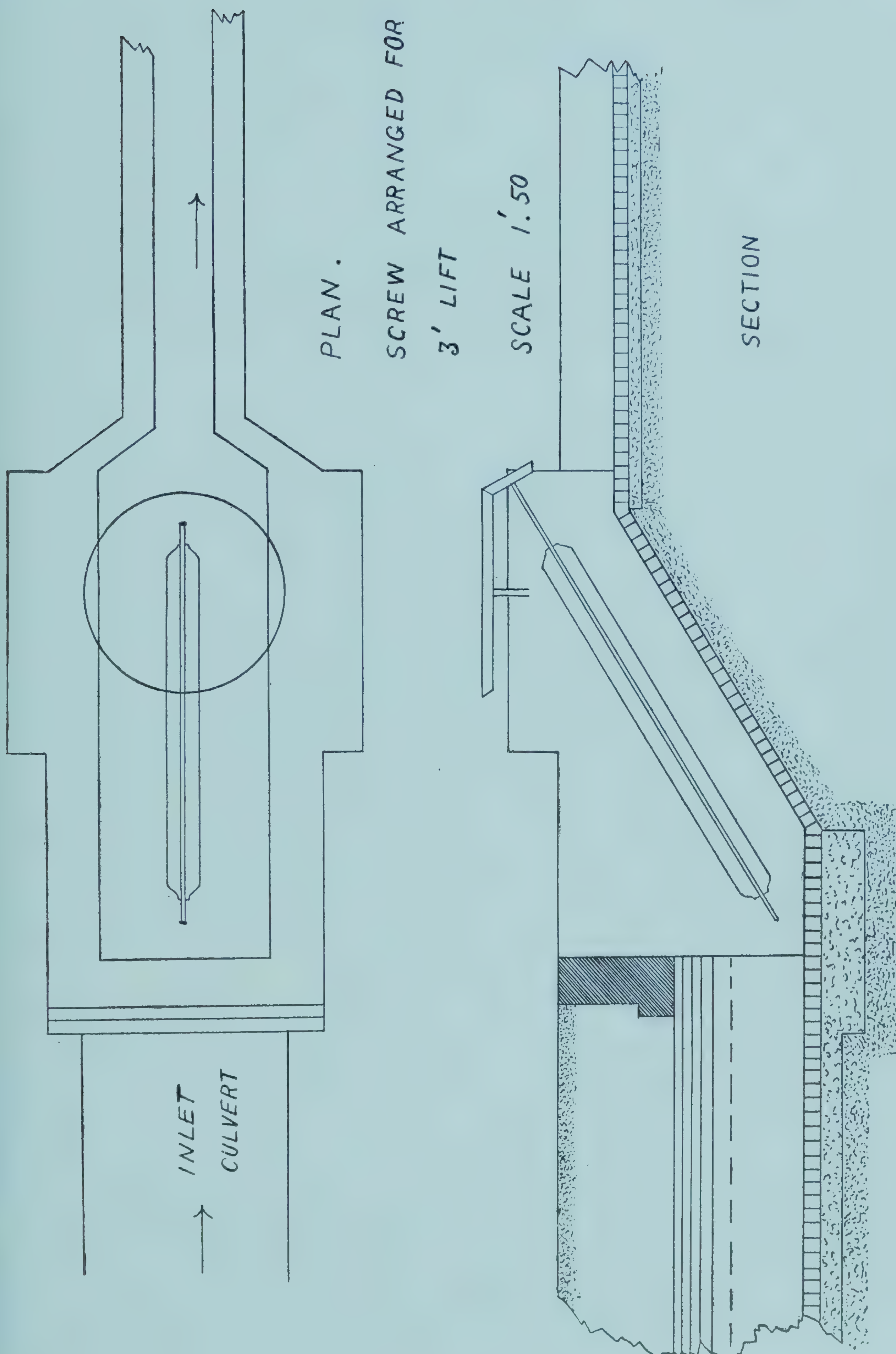
In working, the grain is put in a heap on the threshing floor and a thin layer spread out round the circumference of the heap. The Norag is driven round this and the straw kept carefully turned. Fresh material is gradually taken from the heap, which gradually diminishes in size, till the whole is threshed. The circle also gets less and less in diameter till the lot is finished.

THE "NORAG" OR THRESHING MACHINE.

PLATE V.

ARCHIMEDIAN SCREW WATER-LIFT.

PLATE VI.



PLAN.
SCREW ARRANGED FOR
3' LIFT
SCALE 1'.50
SECTION
INLET
CULVERT

WOOD ARCHIMEDIAN SCREW.

It is necessary to keep the layer of grain which is being threshed thick enough to prevent injury by bruising between ground and the iron discs. Complaints of cutting of grain have been traced to neglect of this precaution.

IV. Archimedian Screw Water-Lift.

On irrigated land there are generally areas which are just above flow water level and a great desideratum is an efficient water-lift driven by animal power to raise water generally not more than 3 feet.

A Persian wheel is often used in India on a 3 feet lift, this is not efficient. A one-bullock Persian wheel on a small lift will discharge from 0·10 to 0·12 cubic foot per second. The photo (Plate V) illustrates a machine, which gives an estimated discharge of nearly 1 cubic foot per second on a 2 feet lift, *i.e.*, will water an acre 1 inch deep in an hour. It consists of a double spiral working in a tight masonry cylinder. The cost is Rs. 600 (pre-war) and unlike the Persian wheel or "Hurla" does not need to be re-made or re-fitted each season. At Mirpur Khas (Sind) the masonry cost Rs. 200; diagrams in Plate VI show how this is constructed.

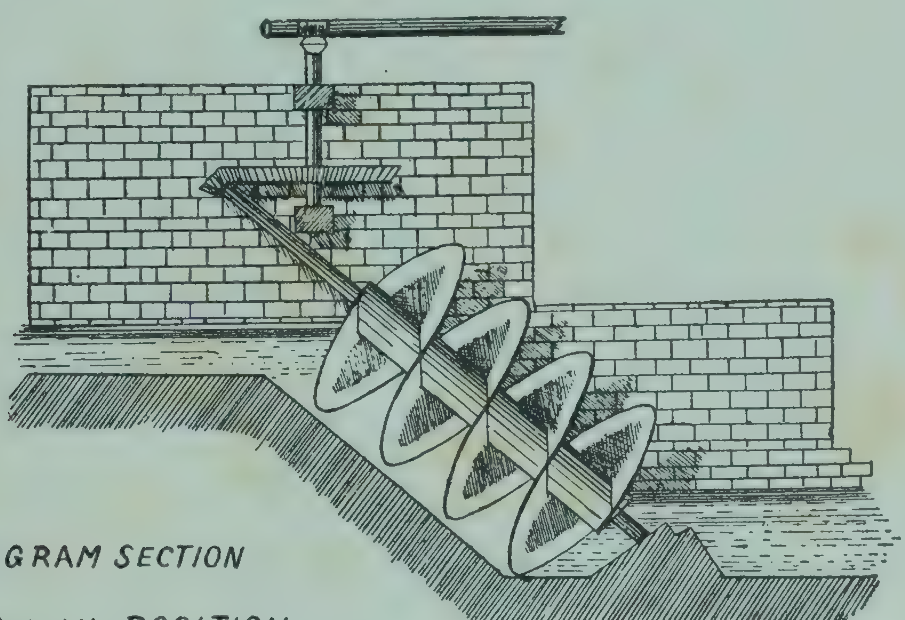


DIAGRAM SECTION OF SCREW IN POSITION

V. Wood Archimedian Screw.

This is a very common implement in Egypt and when water is scarce or at a low level the "Fellaheen" can be seen working it day and night. (Plate VII.)

The centre is composed of a square iron shaft and round this thin pieces of wood are strung. Each piece of wood has a square hole in

the middle, the holes are made at a greater and greater angle, so the slips of wood form a double spiral. The edges of each piece of wood are bevelled to give a smooth passage for the water. Finally the implement is encased in a wood cylinder and a handle put at the end of the shaft. The bottom end is inserted into the water to be lifted. The construction is simple, the length being varied according to need and diameter 14-16 inches.

The out-turn of water is very good, and the implement can be made by any village " mistri."

VI. Dutch Water Wheel.

This is a new patent water-lift (Plate VIII) which is now being used in Egypt. It is also for short lifts.

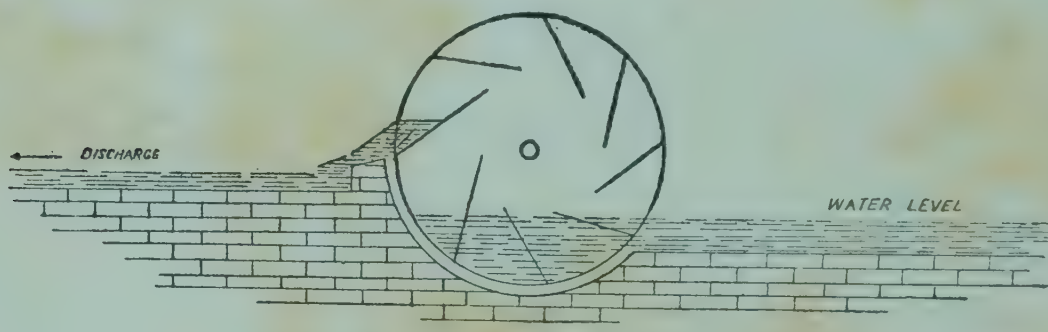


DIAGRAM DUTCH WHEEL

It consists of 2 large iron discs on an axis. Between the discs are vanes set at such an angle (about 40° with the horizon) that water can be lifted between the vanes and the masonry case, till the water is higher than a small wall. When the wheel revolves the water flows over the wall into the irrigation channel.

The wheel is simple and easy to run. Dr. Parr of the United Provinces gave this machine a trial and has favourably reported on it.

CALCUTTA : PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8, HASTINGS STREET.

DUTCH WATER WHEEL.

Second Report on the Experiments carried out at Pusa to improve the Mulberry Silk Industry, compiled under the direction of the Imperial Entomologist.

[*Received for publication on the 14th March, 1917.*]

For the previous records of experiments with the hybrid races of the following Table, Table I, Bulletin No. 48, should be consulted.

In this Table multivoltine races have been crossed with univoltine races to see whether a multivoltine hybrid race which will yield better cocoons than pure multivoltine races, can be established.

TABLE I.

Race and generation		Date of oviposition	Number of univoltine layings	Number of multivoltine layings	Date of hatching	Date of mounting	Number of empty cocoons without pupal skin per 10 grammes	REMARKS
Nistari ♀ × French ♂ } ♂ F_{30} × Mysore ♀	F_2	16th August 1914	105	nil	26th August 1914	14th September 1914	68	For previous generations of this race, *vide* Table I, Bulletin No. 48. About 4 per cent. of the eggs hatched on 26th August 1914 and the rest on 14th April 1915.
Do.	F_3	25th September 1914	16	5	4th October 1914	5th November 1914	85	All the 15 mother moths were healthy.
Do.	F_4	21st November 1914	15	nil	15th December 1914	12th February 1915	140	About 60 eggs from some layings hatched naturally and the rest were sent to cold storage which hatched on 17th February 1915. All the three mother moths were healthy.
Do.	F_5	28th February 1915	nil	3	15th March 1915	10th April 1915	72	One mother moth was attacked with flacherie and the rest were healthy.
Do.	F_6	20th April 1915	3	15	29th April 1915	20th May 1915	70	One female moth was pebrinized and 22 were healthy.
Do.	F_7	29th May 1915	5	18	6th June 1915	27th June 1915	90	All the 24 female moths were healthy.
Do.	F_8	6th July 1915	5	19	14th July 1915	2nd August 1915	90	Four female moths were attacked with flacherie and 9 were healthy.
Do.	F_9	11th August 1915	1	12	19th August 1915	8th September 1915	95	Twelve female moths were attacked with flacherie and 29 were healthy.
Do.	F_{10}	17th September 1915	9	32	25th September 1915	14th October 1915	90	All the 41 female moths were healthy.
Do.	F_{11}	24th October 1915	5	36	2nd November 1915	1st December 1915	95	All the 42 female moths were healthy.
Do.	F_{12}	28th December 1915	36	11	3rd February 1916	16th March 1916	125	All the 11 female moths were healthy.

Do.	F_{13}	28th March 1916	nil	11	6th April 1916	29th April 1916	..	Eight female moths were pebrinized and 109 were healthy.
Do.	F_{14}	9th May 1916	3	116	17th May 1916	..	..	....
Nistari ♀ × French ♂ × Mysore ♀ ♂ × Mysore ♀ ♂	F_1	21st August 1914	nil	all	29th August 1914	19th September 1914	72	Only multivoltine layings were reared in this as well as in succeeding generations.
Do.	F_2	30th September 1914	10	11	8th October 1914	3rd November 1914	72	1·5 per cent. of the female moths were pebrinized.
Do.	F_3	20th November 1914	61½	6½	8th December 1914	7th February 1915	160	All the 15 female moths examined, were healthy.
Do.	F_4	28th February 1915	nil	15	15th March 1915	10th April 1915	72	6 per cent. of the female moths were attacked with flacherie and the rest were healthy.
Do.	F_5	24th April 1915	nil	20	3rd May 1915	25th May 1915	90	In all two mother moths were examined which were healthy.
Do.	F_6	3rd June 1915	1	1	12th June 1915	2nd July 1915	75	The number of diseased moths was not recorded.
Do.	F_7	12th July 1915	8	12	20th July 1915	8th August 1915	70	80 per cent. of the female moths were attacked with flacherie and the rest were healthy.
Do.	F_8	19th August 1915	1½	28½	27th August 1915	14th September 1915	70	35·5 per cent. of the female moths were attacked with flacherie and the rest were healthy.
Do.	F_9	24th September 1915	22	49	2nd October 1915	20th October 1915	80	All the 16 female moths which were examined were healthy.
Do.	F_{10}	31st October 1915	9	7	11th November 1915	21st December 1915	120	All the 18 female moths that were examined were healthy.
Do.	F_{11}	17th January 1916	10½	7½	13th February 1916	22nd March 1916	120	All the 15 female moths that were examined were healthy.
Do.	F_{12}	2nd April 1916	nil	15	11th April 1916	4th May 1916	100	2 per cent. female moths were pebrinized and 1.5 per cent. were attacked with flacherie and the rest were healthy.
Do.	F_{13}	14th May 1916	11	288	22nd May 1916	17th June 1916	..	....

TABLE I—*concld.*

Race and generation	Date of oviposition	Number of univoltine layings	Number of multivoltine layings	Date of hatching	Date of mounting	Number of empty cocoons without pupal skin per 10 grammes	REMARKS
French ♂ × Nistari ♀ } ♂ × Mysore ♀ } ♀ × Nistari ♀ × Italian-Japanese ♂ } ♂ } F_1	25th May 1915	3	2	1st June 1916	22nd June 1916	85	The results of rearing of the multivoltine races are recorded in this as well as in succeeding generations. All the 6 female moths were healthy.
Do. F_2	2nd July 1915	4	2	10th July 1915	30th July 1915	65	Of the 7 moths examined, 2 were attacked with flacherie and the rest were healthy.
Do. F_3	8th August 1915	1	6	17th August 1915	4th September 1915	75	All the 6 female moths were healthy.
Do. F_4	13th September 1915	nil	6	22nd September 1915	11th October 1915	85	Of the 29 female moths examined, one was attacked with flacherie and the rest were healthy.
Do. F_5	20th October 1915	10	19	5th March 1916	6th April 1916	..	The univoltine eggs were reared in this generation and the eggs were sent to cold storage for hibernation. Of the 6 female moths examined 2 were attacked with pebrine and the rest were healthy.
Do. F_6	16th April 1916	1	5	25th April 1916	21st May 1916	..	The heat was abnormal this year and many died in the caterpillar stage and spun very poor cocoons. Of the 8 female moths examined, 1 was pebrinized and the rest were healthy.
Do. F_7	30th May 1916	5	3	8th June 1916			

TABLE II.

Race	Number of multivoltine layings	Number of univoltine layings	Weight of eggs reared	Weight of leaves fed to the worms	Weight of green cocoons	Weight of raw silk	Price of raw silk and waste	REMARKS
Nistari ♀ × French ♂ } ♂ } ♂ × Mysore ♀ × Mysore ♀ The results of this brood were not satisfactory as the temperature was very high this year when the worms were reared.	135 All the eggs were not reared.	47	1 oz.	35 maunds of bush leaves. Local men have been turned into rearers and therefore there is considerable waste of leaves.	40 seers (1 seer=2 lb.)	2 seers 9 chattacks. Average denier of 450 metres=13-15. Average tenacity for the same 36.80 grammes. Average elasticity for the same 17.08 per cent. The silk was reeled uniformly in a filature. The yield would have been more if *khumroo* (coarse) raw silk was obtained from the cocoons.	The price of raw silk=Rs. 33-0-0. The price of waste =₨1-8.	Eggs of another race were supplied to Umar Ali Biswas who obtained $3\frac{3}{4}$ seers of Khumroo raw silk from one maund of cocoons whereas from one maund of Nistari cocoons of the same Bund he obtained 3 seers of raw silk.
Madagascar ♀ × French ♂ } F_1 . .	4	nil	..	..	1 lb.=300 raw cocoons	..	..	
Do. F_2 . .	160	nil	..	..	1 lb.=400 raw cocoons	..	..	Few eggs from some of these layings were univoltine.
Do. F_3 . .	128	nil	..	..	1 lb.=400 raw cocoons	..		
Do. F_5 . .	305	nil	..	..	1 lb.=350 raw cocoons	..	..	

From the above table it will be seen that about 2 seers 9 chattacks of fine raw silk or 3 seers 12 chattacks of *khumroo* (coarse) raw silk were obtained from 40 seers of raw cocoons. The yield of cocoons from 1 oz. of eggs was 40 seers.

Better cocoons have been obtained from the three hybrid races than from the pure multivoltine races generally reared in Bengal, Assam and Burma. But they have not yet turned purely multivoltine. It appears that it will not be possible to get all the layings multivoltine from a hybrid race ; a few layings at least will be univoltine in almost all the generations but, taking the yield of silk into consideration, the few univoltine layings can be discarded and multivoltine layings can be reared profitably. It is hoped that these hybrid races will yield more silk than pure multivoltine ones and perhaps the proper time has now come to introduce them in the rearing districts of Bengal.

It will be seen from the following table that if two pure multivoltine races are crossed, a few layings may become univoltine in some later generations. The hybrid univoltine eggs exhibit the characteristics of pure univoltine races but they hatch uniformly and regularly after a few months even if they are not sent to cold storage for hibernation ; the natural local temperature is quite sufficient to make them hatch uniformly.

It has been seen that, by eliminating all the yellow cocoons from each generation and keeping only the white ones for reproduction, it is easy to get all white cocoons from a mongrel race ; but it is difficult to get all yellow cocoons after many generations if white ones are eliminated in each generation and yellow ones are kept for reproduction. The number of white and yellow cocoons in each generation of the mongrel races are recorded in the remarks column. It will be seen that mongrel races yield better silk than pure multivoltine races up to some generations ; but that ultimately degeneration sets in and then there is practically no difference between the mongrel races and the pure races.

We have seen that multivoltine Madagascar race and its crosses with the indigenous multivoltine races yield cocoons superior to those of the best indigenous multivoltine races and their crosses.

When the Assam race (multivoltine) was crossed with the Chotopolu race all the layings were multivoltine even up to the 8th generation.* It should be noted that, if the moths of the same multivoltine races, obtained from one place or from different localities, are crossed, the eggs remain multivoltine in all the generations. Hence it appears that the Assam and the Chotopolu races are one and the same.

* The "mongrel" race could not be continued after 8th generation on account of scarcity of leaves.

TABLE III.

Race	Number of univoltine layings	Number of multivoltine layings	Date of oviposition	Date of hatching	Date of mounting	Number of empty cocoons without pupal skin per 10 grammes	Remarks
Mysore ♀ × Nistari ♂ F_{28}	nil	50	14th October 1914	25th October 1914	21st November 1914	108	For previous generations, *vide* Bulletin No. 48, page 17. 3·5 per cent. of the mother moths were pebrinized and the rest were healthy. The worms spun 3,555 yellow cocoons and 104 white ones. Yellow ones were kept for reproduction in all the generations.
Do. F_{29}	12½	15½	11th December 1914	9th January 1915	21st February 1915	140	All the mother moths were healthy. The worms spun 272 yellow cocoons and 3 white ones.
Do. F_{30}	nil	16	10th March 1915	24th March 1915	17th April 1915	136	Number of diseased moths not recorded. All the cocoons were yellow.
Do. F_{31}	nil	18	26th April 1915	4th May 1915	25th May 1915	100	All the mother moths were healthy.
Do. F_{32}	nil	19	31st May 1915	8th June 1915	28th June 1915	90	About 6·5 per cent. of the female moths were affected with flacherie and the rest were healthy. The worms spun 1,923 yellow cocoons and 19 white ones.
Do F_{33}	nil	16	8th July 1915	16th July 1915	4th August 1915	100	About 9 per cent. of the mother moths were affected with pebrine and the rest were healthy.
Do. F_{34}	4	252	13th August 1915	21st August 1915	9th September 1915	70	20 per cent. of the mother moths were affected with pebrine and the rest were healthy. All the cocoons were yellow.
Do. F_{35}	12	10	18th September 1915	26th September 1915	15th October 1915	90	All the mother moths were healthy. All the cocoons were yellow.
Do. F_{36}	1	9	25th October 1915	3rd November 1915	30th November 1915	110	4·5 per cent. of the mother moths were attacked with flacherie and the rest were healthy. The worms spun 801 yellow cocoons and 7 white ones.
Do. F_{37}	14	32	26th December 1915	28th January 1916	13th March 1916	165	All the 105 mother moths were healthy. All the 212 cocoons were yellow.

TABLE III—*contd.*

Race	Number of univoltine layings	Number of multivoltine layings	Date of oviposition	Date of hatching	Date of mounting	Number of empty cocoons without pupal skin per 10 grammes	Remarks
Mysore ♀ × Nistari ♂ F_{38}	nil	14	23rd March 1916	2nd April 1916	24th April 1916	..	1·5 per cent. of the mother moths were pebrinized and the rest were healthy. All the 305 cocoons were yellow.
Do. F_{39}	nil	140	5th May 1916	14th May 1916	7th June 1916	..	....
Assam ♀ × Nistari ♂ F_1	nil	all	2nd December 1914	8th February 1915	28th February 1915	120	All the 15 mother moths were healthy. The worms spun 40 yellow cocoons in all. Yellow cocoons were kept for reproduction in all the generations and white ones were destroyed.
Do. F_2	nil	15	28th February 1915	15th March 1915	9th April 1915	90	Two female moths were attacked with flacherie and 19 were healthy. The worms spun 1,070 yellow cocoons which were kept for reproductive purposes in this as well as in succeeding generations and 362 white cocoons.
Do. F_3	nil	21	19th April 1915	28th April 1915	18th May 1915	80	All the 13 mother moths were healthy. The worms spun 144 white cocoons and 972 yellow cocoons.
Do. F_4	nil	13	28th May 1915	5th June 1915	25th June 1915	95	All the 24 female moths were healthy. The worms spun 585 yellow cocoons and 86 white cocoons.
Do. F_5	nil	24	4th July 1915	12th July 1915	9th August 1915	90	One female moth was attacked with flacherie and 8 were healthy. The worms spun 256 yellow cocoons and 7 white ones.
Do. F_6	nil	9	9th August 1915	18th August 1915	6th September 1915	80	All the 12 mother moths were healthy. All the cocoons were yellow.
Do. F_7	1	11	14th September 1915	22nd September 1915	11th October 1915	70	All the 44 female moths were healthy. All the 185 cocoons were yellow.
Do. F_8	22	22	20th October 1915	29th October 1915	24th November 1915	95	One mother moth was pebrinized and 10 were healthy.

Assam ♀ × Chotopolu ♂	F_1	nil	all	30th November 1914	24th December 1914	3rd March 1915	144	All the 15 mother moths were healthy. All the cocoons were yellow. Pure Chotopolu race spun yellow cocoons and Assam race greenish white cocoons.
Do.	F_2	nil	15	3rd March 1915	18th March 1915	24th April 1915	135	All the 23 mother moths were healthy. The worms spun 55 white cocoons and 205 yellow ones. White cocoons in this as well as in succeeding generations were destroyed and yellow cocoons were kept for reproductive purposes.
Do.	F_3	nil	23	24th April 1915	3rd May 1915	27th May 1915	135	One female moth was pebrinized and 7 were healthy. The worms spun 42 white cocoons and 380 yellow ones.
Do.	F_4	nil	8	5th June 1915	13th June 1915	3rd July 1915	104	The number of diseased moths was not recorded. The worms spun 21 white and 137 yellow cocoons.
Do.	F_5	nil	19	12th July 1915	20th July 1915	9th August 1915	100	One female moth was attacked with flacherie and 16 were healthy. The worms spun 646 yellow cocoons and 56 white ones.
Do.	F_6	nil	17	19th August 1915	29th August 1915	16th September 1915	105	Seven female moths were attacked with flacherie, one was pebrinized and 25 were healthy. The worms spun 287 yellow and 9 white cocoons.
Do.	F_7	nil	33	26th September 1915	4th October 1915	24th October 1915	98	One female moth was attacked with pebrine and 4 were healthy. The worms spun 287 yellow and 13 white cocoons.
Do.	F_8	nil	5	6th November 1915	19th November 1915	8th January 1916	..	The race was discontinued as sufficient leaves were not available in winter.
Nistari ♀ × Chotopolu ♂	F_7	nil	3	28th February 1915	17th March 1915	14th April 1915	140	For previous generations of this race, *vide* First Report, Table XI, page 26. In all two mother moths were examined which were healthy. The worms spun 9 yellow and one white cocoons. Yellow cocoons only were kept for reproduction and white ones were destroyed in all the generations.
Do.	F_8	nil	2	23rd April 1915	2nd May 1915	22nd May 1915	98	One mother moth was pebrinized and 9 were healthy. The worms spun yellow cocoons only.
Do.	F_9	nil	10	31st May 1915	8th June 1915	28th June 1915	105	All the 19 female moths were healthy. The worms spun 670 yellow cocoons and 8 white ones.
Do.	F_{10}	nil	19	6th July 1915	14th July 1915	2nd August 1915	85	Five female moths were attacked with flacherie and 14 were healthy. The worms spun 145 yellow cocoons in all.

TABLE III—*concld.*

Race	Number of univoltine layings	Number of multivoltine layings	Date of oviposition	Date of hatching	Date of mounting	Number of empty cocoons without pupal skin per 10 grammes	REMARKS
Nistari ♀ × Chotopolu ♂ F_{11} . . .	1	18	10th August 1915	20th August 1915	8th September 1915	90	Six mother moths were attacked with flacherie and 24 were healthy. The worms spun 692 yellow cocoons and 36 white ones.
Do. F_{12} . . .	nil	30	17th September 1915	25th September 1915	13th October 1915	95	One female moth was attacked with flacherie and 39 were healthy. The worms spun 610 yellow cocoons and 50 white ones.
Do. F_{13} . . .	nil	40	22nd October 1915	3rd November 1915	1st December 1915	110	The worms spun 561 yellow cocoons and 63 white ones.
Do. F_{14} . . .	29	26	27th December 1915	29th January 1916	10th March 1916	160	All the 18 female moths were healthy. The worms spun 467 yellow cocoons and 27 white ones.
Do. F_{15} . . .	nil	18	22nd March 1916	2nd April 1916	25th April 1916	..	One female moth was pebrinized and 12 were healthy.
Do. F_{16} . . .	nil	100	..	..	..	..	The race was discontinued.

Mr. Kawahito, the Director of Aichiken Sericulture Experimental Station, Japan, has been reported to get an improvement in the cocoons of univoltine races by immersing the eggs in dilute hydrochloric acid. The following experiment was carried out here on a similar line with a multivoltine race and the result is shown below.

TABLE IV.

Race	Treatment of eggs	Date of oviposition	Date of hatching	Number of cocoons per 10 grammes
Assam ♀ × Chotopolu ♂ } F_7	Normal eggs . .	26th September 1915	4th October 1915	13 raw, 80 pierced, 90 empty.
Do.	Eggs dipped in dilute hydrochloric acid from 8-30 P.M. of 3rd October 1915 to 6 A.M. of 4th October 1915	Do.	Majority hatched on 4th October 1915 but a few on 5th October 1915	15 raw, 85 pierced, 105 empty.
Do.	Eggs dipped in dilute hydrochloric acid from 8-30 P.M. of 3rd October 1915 to 3 A.M. of 4th October 1915	Do.	Few eggs hatched on 4th October 1915 but the majority hatched on 5th October 1915	13 raw, 80 pierced, 90 empty.

Thus it is seen that better cocoons were not obtained by keeping eggs of multivoltine races in dilute hydrochloric acid.

The following experiment was undertaken to see whether better cocoons can be obtained by increasing the number of feedings, the conditions of rearing remaining the same.

TABLE V.

Race	Date of hatching	Date of mounting	Number of feedings per day	Number of cocoons per 10 grammes
Multivoltine hybrid race	10th July 1915	30th July 1915	12	10 raw, 65 pierced, 70 empty.
Do.	10th July 1915	1st August 1915	9	9 raw, 60 pierced, 70 empty.
Do.	Do.	Do.	8	11 raw, 75 pierced, 80 empty.
Do.	Do.	Do.	6	12 raw, 70 pierced, 80 empty.
Do.	9th July 1915	28th July 1915	6	10 raw, 65 pierced, 75 empty.

It is seen that the yield of silk can be increased by increasing the number of feedings but the advantage obtained is not proportionate to the extra trouble and cost required for the purpose.

The following experiment was undertaken to find out which variety of mulberry gives the most satisfactory results in the yield and other qualities of silk and the percentage of diseases in the mother moths.

The following varieties of mulberry were used in this experiment :—

1. *Morus indica*, male.
2. *Morus indica*, female.
3. Bengal bush.
4. Philippine variety.
5. Japanese variety.
6. Italian variety.

TABLE VI.

Race	Variety of mulberry leaves served to the worms	Date of hatching	Date of maturity	Number of cocoons per 10 grammes	Percentage of pebrinized moths	Percentage of healthy moths	Average length of thread in one cocoon in metres	Average denier of one filament for the length of 450 metres	Average denier of five filaments for the length of 450 metres	Average tenacity for the length of 450 metres	Percentage of elasticity for the same
Boropolu ♀ × Japanese ♂ } F_1	*Morus indica*, male medium tree	3rd March 1916	1st April 1916	13 raw, 75 pierced, 105 empty	29	71	371·43	1·75	9·50	39·3	8·88
Do.	*Morus indica*, female medium tree	4th March 1916	Do.	12 raw, 75 pierced, 100 empty	30	70	364·64	1·87	9·75	33·0	14·66
Do.	*Morus alba* var. *indica*, Bengal bush	5th March 1916	4th April 1916	13 raw, 75 pierced, 105 empty	35	65	349·00	1·87	9·00	32·4	13·40
Do.	*Morus alba* var. *philippinensis*, tree	Do.	3rd April 1916	11 raw, 80 pierced, 100 empty	43	57	413·51	1·64	9·00	35·4	15·20
Do.	*Morus alba* var. *japanica*, tree	Do.	Do.	10 raw, 70 pierced, 85 empty	30	70	467·00	1·78	9·00	33·7	12·74
Do.	*Morus alba* of Italy, tree	Do.	Do.	14 raw, 100 pierced, 135 empty	41	59	330·00	1·58	7·50	29·6	12·10

Taking the yield of silk and other things into consideration Japanese mulberry stands first, Philippine variety and *Morus indica*, female, stand second; Bengal bush and *Morus indica*, male, stand third and Italian variety stands last. It should be noted that a crop of leaf can be obtained from Japanese and Philippine varieties earlier in the spring, so that the spinning of cocoons may begin before the advent of the hot season. The Japanese variety yields many fruits but the Philippine variety yields very few, about 90 per cent. of the flowers being males. There is practically no difference between the leaves of male and female varieties of *Morus indica* though the latter gave a little better result than the former; the female variety yields many fruits but the male one does not bear a single fruit, all the flowers being males. The leaves of the Italian variety are very big and hard and not suitable for feeding the worms. The Bengal bush variety does not bear fruits as it is not allowed to grow more than 4 or 5 feet high. This variety would no doubt yield better results if it is allowed to grow into a big tree.

The leaves of the six varieties of mulberry were analysed in the Chemical Laboratory of Pusa with the following results :—

TABLE VII.

	Morus indica, male medium tree	*Morus indica*, female medium tree	*Morus alba* var. *indica*, Bengal bush	*Morus alba* var. *philippinensis*	*Morus alba* var. *japanica*	*Morus alba* of Italy
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	68·82	69·30	65·69	66·63	64·46	69·02
Dry matter	31·18	30·70	34·31	33·37	35·54	30·98
	Per cent. on dry matter	Per cent. on dry matter	Per cent. on dry matter	Per cent. on dry matter	Per cent. on dry matter	Per cent. on dry matter
Organic matter	86·39	85·93	84·19	86·57	86·66	90·50
Fat, resinous substances, etc.	3·86	3·73	4·03	3·43	5·06	3·40
Pure protein	24·40	23·93	26·54	17·81	20·49	16·09
Crude protein	27·05	25·85	28·82	19·68	21·88	16·50
Nitrogenous non-albuminous substance	2·65	1·93	2·28	1·87	1·39	0·81
Soluble carbohydrate	50·41	50·63	46·90	56·54	52·96	62·28
Woody fibre	7·72	7·64	7·32	8·79	8·15	8·73
Ash	13·61	14·07	15·21	13·43	13·34	9·50

One of the dangerous diseases of silkworms is pebrine which is hereditary and contagious. It is essential that the eggs, laid by a mother moth

which is attacked with pebrine, should be destroyed and only those laid by healthy moths should be used for reproductive purposes. The contagious and hereditary nature of the disease is apparent from the following experiments carried out at Pusa in August 1911. All the worms used in the experiment were kept in the same room and the conditions of rearing were the same as are generally followed by the cultivators. The average temperature and moisture-content of the room from the date of hatching to that of maturity were as under.

Date	Average dry temperature of the rearing room	Average humidity of the air of the rearing room
	° F.	Per cent.
15th August 1911	82·5	88·0
16th " "	82·5	91·5
17th " "	84·5	85·5
18th " "	82·5	89·5
19th " "	81·5	90·5
20th " "	80·8	93·5
21st " "	81·0	93·0
22nd " "	80·5	91·0
23rd " "	79·5	91·5
24th " "	81·5	91·5
25th " "	82·5	87·5
26th " "	82·5	88·0
27th " "	81·5	93·0
28th " "	82·5	88·5
29th " "	83·5	83·5
30th " "	82·5	86·5
31st " "	82·5	88·5
1st September 1911	84·5	85·0
2nd " "	84·5	83·5
3rd " "	83·0	85·5
4th " "	83·5	85·0
5th " "	83·5	85·5
6th " "	83·0	88·0
7th " "	81·5	91·5
8th " "	79·5	92·5
9th " "	82·5	86·5

In this experiment (1) 10 healthy and 2 pebrinized layings, (2) 10 healthy and 3 pebrinized layings, (3) 10 healthy and 7½ pebrinized layings, (4) 10 healthy and 5 pebrinized layings, (5) 10 healthy and 10 pebrinized layings, (6) 10 healthy layings, (7) 10 healthy and 2½ pebrinized layings, (8) 10 healthy and one pebrinized layings, (9) 10 healthy and ½ pebrinized layings, (10) 4 pebrinized layings and 10 healthy ones and (11) 10 pebrinized layings were reared separately in the same room in 11 consignments and their results are recorded in Table VIII.

TABLE VIII.

	Race	Number of healthy layings	Number of pebrinized layings	Number of worms reared	Number of cocoons obtained	Weight of cocoons obtained	Percentage of pebrinized moths	Percentage of healthy moths	REMARKS
						Chattacks			
1	Nistari ♀ × Mysore ♂ } F_5	10	2	3,740	504	6	67·5	32·5	Healthy and diseased worms were mixed and reared together.
2	Do. . .	10	3	4,015	740	7½	96·0	4·0	Do.
3	Do. . . .	10	7½	5,162	1,163	13½	100·0	nil	Do.
4	Do. . . .	10	5	4,475	603	7	96·0	4·0	Do.
5	Do. . . .	10	10	5,850	507	6½	86·0	14·0	Do.
6	Do. . . .	10	nil	3,197	921	10	78·0	22·0	Healthy eggs only were reared in this consignment.
7	Do. . . .	10	2½	3,787	1,683	18¼	88·0	12·0	Healthy and diseased worms were mixed and reared together.
8	Do. . . .	10	1	3,373	1,145	11½	94·5	5·5	Do.
9	Do. . . .	10	½	3,237	1,021	11	67·5	32·5	Do.
10	Do. . . .	10	4	4,200	1,058	12¾	30·0	70·0	Do.
11	Do. . . .	nil	10	2,753	35	..	100·0	nil	Only diseased eggs were reared in this consignment.

It has been seen that the best results were obtained from 10 healthy layings and the worst from the 10 layings laid by diseased moths. From the 10 healthy layings 921 cocoons were obtained, whereas, from the 10 diseased layings only 35 cocoons were obtained and from the consignment in which 10 healthy and 10 diseased layings were reared only 507 cocoons were obtained. The greater the number of diseased layings reared with the 10 healthy layings, the less were the number of cocoons obtained and the percentage of diseased moths in each consignment was more or less in proportion to the number of diseased layings reared with the 10 healthy layings. It should be noted in this connection that all the eggs laid by a pebrinized moth do not contain pebrine germs. Pebrine spores can be seen in some of the eggs and these multiply with the growth of the embryos but the majority of the eggs are quite healthy. Pebrine spores cannot be seen in the eggs laid by a moth whose generative organ is not attacked with pebrine; if the moth is attacked with pebrine in other parts the germs of the disease may be visible on the egg-shells but these can be washed off with water. Good cocoons and disease-free moths can be obtained from a pebrinized laying if the worms are reared separately and if special care is taken. On the other hand, bad cocoons and diseased moths are obtained from a healthy laying if the worms are not properly attended to and if the temperature and moisture-content in the air are high.

A rearing of the above race was commenced at the same time with healthy layings in a separate room on a large scale. The crop was a successful one; about 94 per cent. of the hatched worms spun cocoons and only 4 per cent. of the female moths were pebrinized.

It has been shown in the First Report that univoltine races are more susceptible to the disease than multivoltine races in a climate like that of Pusa.

In Assam where mulberry silkworm is reared only on a small scale and in the households of cultivators, diseased eggs are not eliminated by the microscopical examination of the moths and the percentage of this disease in moths is about 3 to 4. The room in which the worms are reared is kept very neat and clean and a fire is moreover kept in the rearing room. On account of the cleanliness and the smoke of the fire the germs of the pebrine are kept in check. In Bengal about 50 per cent. pebrine is seen in moths of those localities where microscopical examination is not practised and the worms of many rearers perish on account of this disease. In Japan and Europe where microscopical examination of the moths is undertaken pebrine is present in about 4 to 5 per cent. of the moths.

It has been noticed that the disease is more prevalent during the months of May to October than from November to April. Moisture

and heat appear to help the rapid multiplication of pebrine. A high temperature and moisture-content in the air are not suitable for the healthy development of the worms especially when they are meant to be used for reproductive purposes though these conditions cause a rapid growth of the worms. Pebrine spores may enter into the system of the worms with the leaves eaten by them. Worms may also contract the disease through wounds on their bodies.

It is advisable to keep the mother moths in a box for about four hours only, isolated in paper bags on the second day after oviposition, the temperature of which should be about 180°F, and crush them well in separate pestles and mortars on the 6th or 7th day after oviposition for the Pasteur system of examination. The bags containing the moths can also be dried by exposing them in the sun. The number of the bag containing a moth should correspond with the number of the laying oviposited by it so that the eggs laid by each moth can be ascertained and those laid by diseased moths can be destroyed after examination.

There is another disease of silkworms called flacherie which, according to some, is hereditary but according to others not so. During the rains when the temperature is high and the air is wet many moths are attacked with flacherie though they oviposit the normal number of eggs. The following experiment was undertaken to find out whether good crops could be obtained from eggs laid by moths attacked with flacherie and the results are compared with the cocoons obtained from eggs laid by healthy moths of the same races. All the worms were reared in the same room and under similar conditions.

TABLE IX.

Race	Diseased or healthy eggs	Date of hatching	Date of maturity	Rearing whether successful	Number of cocoons in 10 grammes	Percentage of moths attacked with flacherie	Percentage of moths attacked with pebrine	Percentage of healthy moths	REMARKS
Mysore ♀ × Nistari ♂ F_{35}	Healthy	4th July 1914	23rd July 1914	Successful	13 raw and 95 empty	5	4	91	The eggs were disinfected with 2 per cent. $CUSO_4$ solution.*
Do.	Eggs laid by moths attacked with flacherie	Do.	Do.	Do.	10 raw and 86 empty	25	4	71	
Mysore ♀ × Nistari ♂ F_{36}	Healthy	9th August 1914	27th August 1914	Do.	12 raw and 96 empty	9·3	6·2	84·5	The eggs were disinfected with $CUSO_4$ solution.
Do.	Eggs laid by moths attacked with flacherie	10th August 1914	28th August 1914	Do.	12 raw and 98 empty	68	6	26	
Mysore ♀ × Nistari ♂ F_{34}	Do.	21st August 1915	9th September 1915	Do.	12 raw and 90 empty	8	nil	92	
Do.	Healthy	Do.	Do.	Do.	10 raw and 70 empty	20	nil	80	The eggs were disinfected with $CUSO_4$ solution.
Chotopolu	Eggs laid by moths attacked with flacherie	21st September 1915	12th October 1915	Do.	12 raw and 95 empty	14	nil	85	
Do	Healthy	22nd September 1915	13th October 1915	Do.	13 raw and 105 empty	4	nil	96	The eggs were disinfected with $CUSO_4$ solution.
Nistari	Do.	28th September 1915	18th October 1915	Do.	12 raw and 90 empty	nil	nil	100	
Do.	Eggs laid by moths attacked with flacherie	30th September 1915	20th October 1915	Do.	13 raw and 100 empty	nil	nil	100	
Hybrid race, 8th generation	Do.	23rd September 1915	13th October 1915	Do.	9 raw and 70 empty	5	nil	95	The grandmothers of this consignment were also attacked with flacherie.
Do.	Healthy eggs	24th September 1915	12th October 1915	..	8 raw and 65 empty	6	nil	94	The grandmothers of this consignment were healthy.
Hybrid race, 9th generation	Eggs laid by moths attacked with flacherie	2nd November 1915	1st December 1915	Do.	11 raw and 80 empty	nil	nil	100	The grandmothers and great grandmothers of this lot were attacked with flacherie.
Do.	Healthy eggs	31st October 1915	28th November 1915	Do.	10 raw and 72 empty	nil	nil	100	The grandmothers and great grandmothers of this lot were healthy.

*For disinfecting rearing rooms and appliances formaline is the best though it is very expensive (*Vide* Bull. No. 39, page 5). SO_2 gas is not effective for the purpose. Pebrine spores cannot be killed with $CUSO_4$ solution. The rearing appliances can be disinfected with steam.

Hence we can conclude that the eggs, laid by moths which were attacked with flacherie, can be safely kept for industrial purposes though in some cases the cocoons are a little inferior to those obtained from the eggs laid by healthy moths.

In the First Report it has been shown that the temperature suitable for the uniform hatching of univoltine eggs is about 30°-40°F. and that it is quite possible to preserve the eggs in Hill Stations such as Shillong, Simla, Naini Tal, Darjeeling, etc., where the natural temperature in winter (from October to February) varies from 60°-30° F. and that the duration of cold storage should be about four months (*vide* Bulletin No. 48, pages 1, 2 and 23).

The following experiment was undertaken to find out whether it is possible to shorten the duration of cold storage by increasing the intensity of cold and to study the effect of intense cold on the embryos. We are indebted to the Director of the King Institute of Preventive Medicine, Guindy, Madras, for keeping the eggs in his cool rooms.*

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* For temperature of cool and cooler rooms, *see* Table XII.

TABLE X.

Race	Date of oviposition	Number of layings	Temperature of the cold storage and treatment there	Duration of hatching	Number of worms hatched	Hatching whether regular	REMARKS
French ♀ × Doropolu ♂ } F_1	24th April 1915	37*	11°-30° F. from 18th June 1915 to 5th November 1915	26th February 1916 to 15th May 1916	5,113	Very irregular	Few hatched on 4th June 1915. The embryos of some were affected and some eggs seemed to be in good condition but they were injured in the cold storage and failed to hatch.
French acclimatized eggs	26th April 1915	20	Do.	18th February 1916 to 12th May 1916	53	Do.	The embryos of some were injured.
Chinese acclimatized eggs	28th April 1915	8	Do.	21st March 1916 to 27th April 1916	15	Do.	The embryos of many were injured.
Japanese ♀ × Boropolu ♂ } F_1	18th April 1915	20	Do.	2nd February 1916 to 20th May 1916	..	..	Few hatched on 4th June 1916. The embryos of many were injured.
Boropolu ♀ × Japanese ♂ } F_1	18th April 1915	21	Do.	28th January 1916 to 15th May 1916	1,453	Irregular	Few hatched on 4th June 1916. The embryos of some were injured.
Boropolu	15th April 1915	4	Do.	28th January 1916 to 30th March 1916	860	Do.	The embryos of few were injured.
Chotopolu ♀ × Boropolu ♂ } F_2	17th May 1915	8	Do.	6th February 1916 to 8th April 1916	719	Do.	The embryos of some were injured.
French ♀ × Chinese ♂ } F_1	28th April 1915	37	Do.	18th February 1916 to 22nd May 1916	271	Do.	The embryos of many were injured.
French ♀ × Nistari ♂ } ♂ × Mysore ♀ } F_4	19th May 1916	3	Do.	2nd February 1916 to 27th April 1916	233	Do.	The embryos of some were injured.
French ♀ × Nistari ♂ } ♂ × Mysore ♀ } ♂ × Mysore ♀ } F_4	Do.	8	Do.	27th January 1916 to 23rd April 1916	651	Do.	Do.
Mysore ♀ × Nistari ♂ } ♀ × French ♂ } ♂ × Chotopolu ♀ } F_3	9th April 1915	11	Do.	26th January 1916 to 17th March 1916	1,822	Do.	The embryos of few were injured and some eggs dried up in the cold storage.
Imported French eggs	July 1915	1 oz. or 40,000	11°-30° F. from 1st November 1915 to 3rd March 1916	25th March 1916 to 25th April 1916	429	Do.	The embryos of many were injured. 3 oz. of eggs of the same lot were sent to Muktesar for cold storage and kept there at 60°-30° F. from 30th October 1915 to 3rd March 1916. All the eggs hatched regularly in five days.

* One laying contains about 350 eggs.

Some of the eggs of the above races were kept in a dark room of the Pusa Silk house from October to March 1915 and they began to hatch non-uniformly from 26th January 1916.

Univoltine eggs of 9 different varieties were divided in five parts and kept in five bags. Each of these bags was treated in cold storage in the following way :—

No. 1 bag kept in the cooler room for one month.

No. 2 bag kept in the cooler room for two months.

No. 3 bag kept in the cool room for 15 days, shifted to the cooler room and kept there for 15 days and shifted back to cool room and kept there for 15 days and then taken out for incubating.

No. 4 bag kept in the cool room for 15 days, shifted to the cooler room and kept there for 32 days and shifted back to cool room and kept there for 15 days and then taken out for incubating.

No. 5 bag kept in the cool room for 3 months.

The results are recorded in the following Table :—

TAB

Race	Date of oviposition	Bag No. 1 kept in cooler room on 20th December 1915 and taken out on 21st January 1916 for incubating				Bag No. 2 kept in cooler room on 20th December 1915 and taken out on 21st February 1916 for incubating			
		Number of layings	Duration of hatching	Number of hatched worms	Remarks	Number of layings	Duration of hatching	Number of hatched worms	Remarks
French	2nd April 1915	½	22nd February 1916 to 15th May 1916	16	The embryos of many eggs were injured	½	21st February 1916 to 24th February 1916	5	The emb were inj and there the wo could come out
Chinese . . .	28th April 1915	3	21st February 1916 to 3rd April 1916	191	Do.	6	21st March 1916 to 24th April 1916	168	Many emb were inj and ho failed hatch
Boropolu	31st March 1915	2	18th February 1916 to 12th March 1916	444	Few eggs did not hatch and seemed to have been injured	3	12th March 1916 to 30th March 1916	753	Some emb were inj and there the eggs co not hatch
Chinese ♀ × French ♂ F_1 . .	28th April 1915	1	12th March 1916 to 17th April 1916	31	Many eggs were injured	1	27th March 1916	2	The rest the embr dried up
Boropolu ♀ × French ♂ F_1 . .	23rd April 1915	1	18th February 1916 to 23rd March 1916	262	Few eggs were injured	1	21st March 1916 to 23rd April 1916	72	Do.
Mysore ♀ × Nistari ♂ ♂ × Boropolu ♀ F_8 . .	3rd December 1915	4	18th February 1916 to 17th March 1916	500	Some eggs did not hatch and some embryos were injured	3	12th March 1916 to 27th March 1916	1178	Very few bryos w injured
Italian ♀ × Japanese ♂ ♂ × Nistari ♀ × Mysore ♀ ♂ F_8	10th December 1915	3	14th March 1916 to 16th April 1916	296	Many embryos were injured and failed to hatch	3	3rd April 1916 to 11th April 1916	16	Most of embryos v injured
Hybrid univoltine eggs . .	24th October 1915	2	18th February 1916 to 3rd April 1916	8	Few embryos were injured and failed to hatch	2	17th March 1916 to 18th April 1916	235	Some embr were injur
Eri eggs	10th December 1915	5	..	nil	All the embryos were injured and failed to hatch	5	..	nil	All the bryos w injured

Bag No. 3 kept in cool room on 20th December 1915, shifted to cooler room on 5th January 1916 and then shifted back to cool room on 20th January 1916 and then kept for incubating on 5th February 1916				Bag No. 4 kept in cool room on 20th December 1915, shifted to cooler room on 5th January 1916, shifted back to cool room on 7th February 1916 and taken out on 21st February 1916 for incubating				Bag No. 5 kept in cool room on 20th December 1915 and taken out on 21st February 1916 and then kept for incubating			
Number of layings	Duration of hatching	Number of hatched worms	Remarks	Number of layings	Duration of hatching	Number of hatched worms	Remarks	Number of layings	Duration of hatching	Number of hatched worms	Remarks
½	21st February 1916 to 5th March 1916	28	Many embryos were injured	½	12th March 1916 to 27th March 1916	2	Most of the embryos were injured in the cold storage	..	..	..	The eggs were missing
5	11th February 1916 to 24th March 1916	446	Some embryos were injured	4	5th March 1916 to 3rd April 1916	810	Some embryos were injured in the cold storage	1	7th March 1916 to 17th March 1916	183	Few embryos were injured in the cold storage
2	18th February 1916 to 5th March 1916	330	Do.	2	5th March 1916 to 12th March 1916	470	Few embryos were injured in the cold storage	4	3rd March 1916 to 9th March 1916	1435	The hatching was satisfactory
1	3rd March 1916 to 21st March 1916	185	Some embryos were injured in the cold storage	1	7th March 1916 to 21st March 1916	242	Very few embryos were injured	3	3rd March 1916 to 14th March 1916	233	Many embryos were injured
1	21st February 1916 to 7th March 1916	231	Few embryos were injured in the cold storage	1	5th March 1916 to 12th March 1916	260	Do.	1	28th February 1916 to 9th March 1916	288	Few embryos were injured
4	26th February 1916 to 7th March 1916	345	Do.	4	5th March 1916 to 9th March 1916	729	1 laying did not hatch at all. The embryos of the rest were in good condition	1	5th March 1916 to 9th March 1916	91	Many embryos were injured
3	18th February 1916 to 14th March 1916	420	Some eggs were injured in cold storage	3	12th March 1916 to 17th March 1916	442	Few embryos were injured in the cold storage	4	7th March 1916 to 12th March 1916	545	Some eggs did not hatch
2	9th February 1916 to 12th March 1916	445	Few eggs were injured in the cold storage	2	5th March 1916 to 12th March 1916	547	Do.	1	3rd March 1916 to 9th March 1916	322	All hatched
5	..	nil	All the embryos were injured in the cold storage	5	..	nil	All the embryos were injured	10	..	..	About half the eggs hatched in the cold storage. The rest dried up. Many broke the egg-shells but could not come out

Thus it has been seen that the period of cold storage can be shortened if the cold is more intense in the hibernating room but many of the embryos are injured and the hatching isnon-uniform and quite unsatisfactory. When the eggs were taken out from the intense cold they seemed to be in good condition but after two to three months slight depressions were visible on the eggs, which later on dried up. The hatching of the eggs, stored in the cool room (where the temperature varied from 30° to 60°F.), was more uniform than in the case of the eggs kept in the cooler room (where the temperature varied from 11° to 30° F.). Eggs properly kept in cold storage should hatch uniformly in a climate like that of Pusa on the 12th or 13th day after taking out of cold storage (*vide* Bulletin No. 48) ; but some of the eggs, sent to the cooler room, hatched irregularly two to three months after taking out of the cold storage and the rest dried up.

The eggs of Boropolu and Japanese races and their hybrids with multivoltine races hatch more uniformly than the eggs laid by other univoltine races under the same conditions. It has been seen further that the air of hibernating room should be pure and dry. Moist air prevents the exhalation of water vapour from the embryos and thus injures them ; very dry air also is injurious to the embryos.

The results also prove that Eri eggs (it should be noted that Eri silkworm is multivoltine) cannot stand a very low temperature and they fail to hatch if they are kept in cold.

Variations of temperature in hibernating rooms weaken the embryos and the worms which come out are feeble. In the worst cases they fail to hatch and die inside the eggs.

It should be noted that the eggs of multivoltine races are not sent for cold storage as they hatch naturally on the 10th to 15th day after oviposition. The hatching may be deferred by keeping them in a low temperature for a few weeks. (*Vide* First Report, page 19.)

Eggs of the above nine univoltine races (not Eri eggs) were also sent to Shillong and Muktesar where they were kept at a temperature varying from 50° to 30° F. These were sent in October and taken out in February for incubating ; almost all the eggs hatched uniformly and regularly in four days on the 12th or 13th day after taking out of the cold storage ; few embryos were injured and the hatching was quite satisfactory. It has been shown in the First Report that the eggs sent for cold storage to an ice factory, where the temperature varied from 35° to 45° F., hatched satisfactorily in three or four days.

In the silk-rearing districts of Japan, there are peculiar contrivances erected on the Hills known as Fu-Ketsu (wind-holes). A small cave is excavated on a hill on a side opposite to that from which wind blows ; the walls and the ceiling of the cave are filled up with saw dust or other non-conductors of heat. In these caves the temperature is always

about 35° to 45° F. when the outside temperature in summer and autumn varies from 45° to 95° F. Eggs are kept in such cold caves for hibernation and taken out in summer and autumn for incubating so that univoltine races can be reared any number of times in a year simply by deferring the hatching. The prosperity of the silk industry in Japan is primarily due to the use of such cold caves. Such caves may perhaps be constructed in the Hills of Upper Shillong and Naini Tal. Suitable cold rooms can also be made in those places where there are ice factories.

TABLE XII.

Maximum and minimum temperatures of the cool and cooler rooms.

Date	Cool room		Cooler room	
	Maximum	Minimum	Maximum	Minimum
	° F.	° F.	° F.	° F.
20th December 1915	59	48	30	19
21st ,, ,,	53	49	28	18
22nd ,, ,,	53	49	27	11
23rd ,, ,,	54	47	25	12
24th ,, ,,	54	49	28	12
25th ,, ,,	..	..	..	..
26th ,, ,,	58	47	31	14
27th ,, ,,	57	45	28	15
28th ,, ,,	..	..	..	..
29th ,, ,,	60	45	30	15
30th ,, ,,	..	..	..	..
31st ,, ,,	60	45	30	13
1st January 1916	..	..	..	..
2nd ,, ,,	60	54	30	13
3rd ,, ,,	56	50	28	12
4th ,, ,,	52	48	27	13
5th ,, ,,	52	48	28	12
6th ,, ,,	52	48	27	13
7th ,, ,,	55	52	26	12
8th ,, ,,	52	45	27	14
9th ,, ,,	..	..	..	..
10th ,, ,,	60	47	30	14
11th ,, ,,	52	45	27	15
12th ,, ,,	52	45	27	13
13th ,, ,,	52	45	25	14
14th ,, ,,	52	45	26	11
15th ,, ,,	52	45	24	13
16th ,, ,,	..	..	..	..
17th ,, ,,	56	45	30	15
18th ,, ,,	..	..	..	..
19th ,, ,,	56	45	25	13
20th ,, ,,	56	44	24	15
21st ,, ,,	54	42	25	12
22nd ,, ,,	52	45	25	11
23rd ,, ,,	..	..	..	..
24th ,, ,,	56	45	28	11
25th ,, ,,	52	47	27	13
26th ,, ,,	60	50	30	11
27th ,, ,,	54	45	30	13
28th ,, ,,	52	45	27	13

TABLE XII—*concld.*

Date	Cool room		Cooler room	
	Maximum	Minimum	Maximum	Minimum
	°F.	°F.	°F.	°F
29th January 1916 . .	52	45	26	13
30th ,, ,, . .	..	..	..	..
31st ,, ,, . .	50	46	30	15
1st February 1916 . .	52	45	27	14
2nd ,, ,, . .	52	45	27	13
3rd ,, ,, .	52	45	25	11
4th ,, ,, . .	52	45	27	13
5th ,, ,, . .	52	42	26	12
6th ,, ,, . .	56	54	26	24
7th ,, ,, . .	56	45	28	15
8th ,, ,, . .	52	45	27	17
9th ,, ,, . .	52	45	27	13
10th ,, ,, . .	52	45	27	14
11th ,, ,, . .	52	45	25	14
12th ,, ,, . .	50	45	27	13
13th ,, ,, . .	54	52	28	24
14th ,, ,, . .	58	45	30	15
15th ,, ,, . .	52	45	28	16
16th ,, ,, . .	52	45	27	13
17th ,, ,, . .	52	45	27	13
18th ,, ,, . .	52	45	27	14
19th ,, ,, . .	52	45	27	13
20th ,, ,, . .	55	49	26	24

Conclusions.

1. Success has been attained in establishing multivoltine hybrid races which will yield better cocoons than the pure multivoltine races generally reared in Bengal, Assam and Mysore. A few eggs from each laying turn univoltine but they should be destroyed and multivoltine eggs should be reared. The loss of these eggs can be ignored considering the advantages gained. About 700, 800, 900, 1,050, 1,100, 1,300, 1,350 and 1,900 raw cocoons of univoltine race, Pusa hybrid No. 1, Pusa hybrid No. 2, Mysore race, Boropolu, Nistari, Chotopolu and Assam race, respectively, weigh 2lb. We recommend to rear Pusa hybrid Nos. 1 and 2 (Multivoltine varieties) in preference to any other varieties from October to April and from May to September respectively. Small quantities of these eggs will be available for distribution from the Imperial Entomologist, Pusa, Bihar if they can be spared when requisition is made for them.

2. All races yield more silk if fed with suitable tree mulberry leaves than when fed with bush leaves. Tree mulberry should be introduced in all localities in addition to bush.

3. Of all the indigenous races, the Mysore race is the best as far as the yield of silk is concerned. The Nistari race should be reared in

April or May, the Mysore race and hybrid races from July to October and univoltine races from October to March.

4. Of all the univoltine races, Chinese and Japanese races thrive best in a climate like that of Pusa but their yield of silk is inferior to those of France and Italy. The cross-breds between Boropolu and foreign univoltine races should be reared in those places where imported foreign races do not thrive well.

5. Univoltine eggs should be hibernated for about 4 or 5 months at about 35° to 45° F. The duration of cold storage can be shortened by the action of intense cold but the hatching of the eggs is quite unsatisfactory.

6. Eggs laid by moths which are attacked with flacherie can be used for industrial purposes.

7. Univoltine races are more susceptible to pebrine than multivoltine ones in a climate like that of Pusa. Pebrine appears more in May to October than in September to April. The more pebrinized layings are reared with healthy layings the less the number of cocoons are obtained from a rearing. The percentage of diseased moths is more or less in proportion to the pebrinized layings reared with healthy layings. Good crops and healthy layings can be obtained from a pebrinized laying if the worms are carefully attended to and if the temperature and moisture-content in the air are suitable for the healthy growth of the worms. Bad crops and pebrinized layings are obtained from a healthy laying if the temperature and moisture-content are high and if the worms are not properly looked after.

8. Multivoltine races cannot be improved by dipping the eggs in dilute hydrochloric acid.

9. *Morus alba* var. *japanica* and *Morus alba* var. *philippinensis* are the best foodstuffs for both univoltine and multivoltine races. There is practically no difference between the male and female varieties of mulberry which have been cultivated at Pusa.

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The Pebrine Disease of Silkworms in India.

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Professor Lefroy in the course of his enquiry into the conditions responsible for the decadence of the Indian Silk Industry, came to the conclusion that one of the principal causes of its present condition is the excessive prevalence of "*Pebrine*," the disease of silkworms which wellnigh extinguished the industry in Europe, in the middle of the nineteenth century. As is well known, Pasteur, after two years' work, demonstrated that the cause of this disease was a protozoon parasite and devised a method of checking its spread and reducing its occurrence to comparatively negligible proportions; this method has now been successfully used in France and Italy for nearly forty years, and was introduced into India some fifteen years since, where it has been adopted in the Government seed-rearing nurseries in Bengal and elsewhere. Professor Lefroy's inquiries showed that as a means of eliminating pebrine the Pasteur method as used in Bengal has been a failure, and it therefore became imperative to determine the reasons for its defective operation in order to discover whether the method itself was inapplicable in this country on account of the difference between European and Indian conditions, or whether some modification of it could be devised which would render it as effective in the East as it has been found in the West. At Professor Lefroy's suggestion I commenced an enquiry into the subject, primarily with a view to determining why the Pasteur method had failed in Bengal and if possible to discover a suitable modification or alternative. This Bulletin is intended as an *interim* report of my investigations to date and is published in order to describe and recommend the trial of a modification of the Pasteur method which I have devised as a result of my enquiries and which has been found successful on a small scale at Pusa.

The Pasteur method. Pasteur's researches resulted in the discovery that certain microscopic bodies ("corpuscules") which some earlier workers had considered to be normal constituents of the body fluids of the silkworm, were in fact parasites responsible for the disease and carried it from one generation to the next through the eggs of the moth. Nearly every diseased moth produces diseased eggs and although every egg in an infected laying is not necessarily diseased yet the percentage is

high enough to ensure serious mortality amongst the worms. In addition to this hereditary infection the disease is also spread by contamination of the food by the droppings of diseased worms which contain pebrine spores, the infection in this case being carried on by ingestion of these spores with the food of the healthy worms. In this way an infected brood or "laying" will spread infection to otherwise healthy worms, so that hereditary infection of a small percentage will result in rapid spread of the disease, and on the other hand if eliminated should go far to extinguish it completely. That such extinction has not been obtained after forty years' use of the method in Europe seems to suggest that as applied in practice it does not afford a complete protection from hereditary transmission even in Europe.

The method itself depends upon the fact that the "Pebrine bodies," the spore form of the parasite, are readily recognizable under a comparatively low power of the microscope, thus making it possible to detect their presence without the use either of expensive apparatus or elaborate technique, in fact this is habitually done by entirely unskilled native rearers in Bengal. This recognizability is due partly to the comparatively large size and characteristic oval shape of the pebrine bodies and partly to their highly refringent character, which makes them clearly distinguishable in the water in which examination takes place from other bodies of similar dimensions which may be present. The body of the moth is crushed with a little water, a drop of the resultant fluid is placed on a slide and examined under a magnification of some 500—600 diameters ; if pebrine bodies are seen the eggs laid by this moth are destroyed, otherwise they are passed as disease-free. Now it will be evident that **the success of this method as a means of eliminating hereditary infection depends upon the general assumption that if there is sufficient disease present in a moth to affect its progeny, its presence will be detectable in the above described manner ;** this is the assumption upon which the successful use of the Pasteur method in Europe depends, but my inquiries appear to show that **so far as India is concerned the method requires serious modification** for the following reasons.

The essential difference between European and Indian conditions, so far as the life history of the mulberry silkworm is concerned, lies in the fact that in Europe the worm is univoltine, *i.e.*, produces only one generation in the year whereas in India the races are in most cases multivoltine, producing seven or eight generations. As a corollary of this difference the eggs of the multivoltine races hatch out within some eight days after laying, whereas in Europe the univoltine eggs are laid in the summer and do not hatch until the following spring. The practical

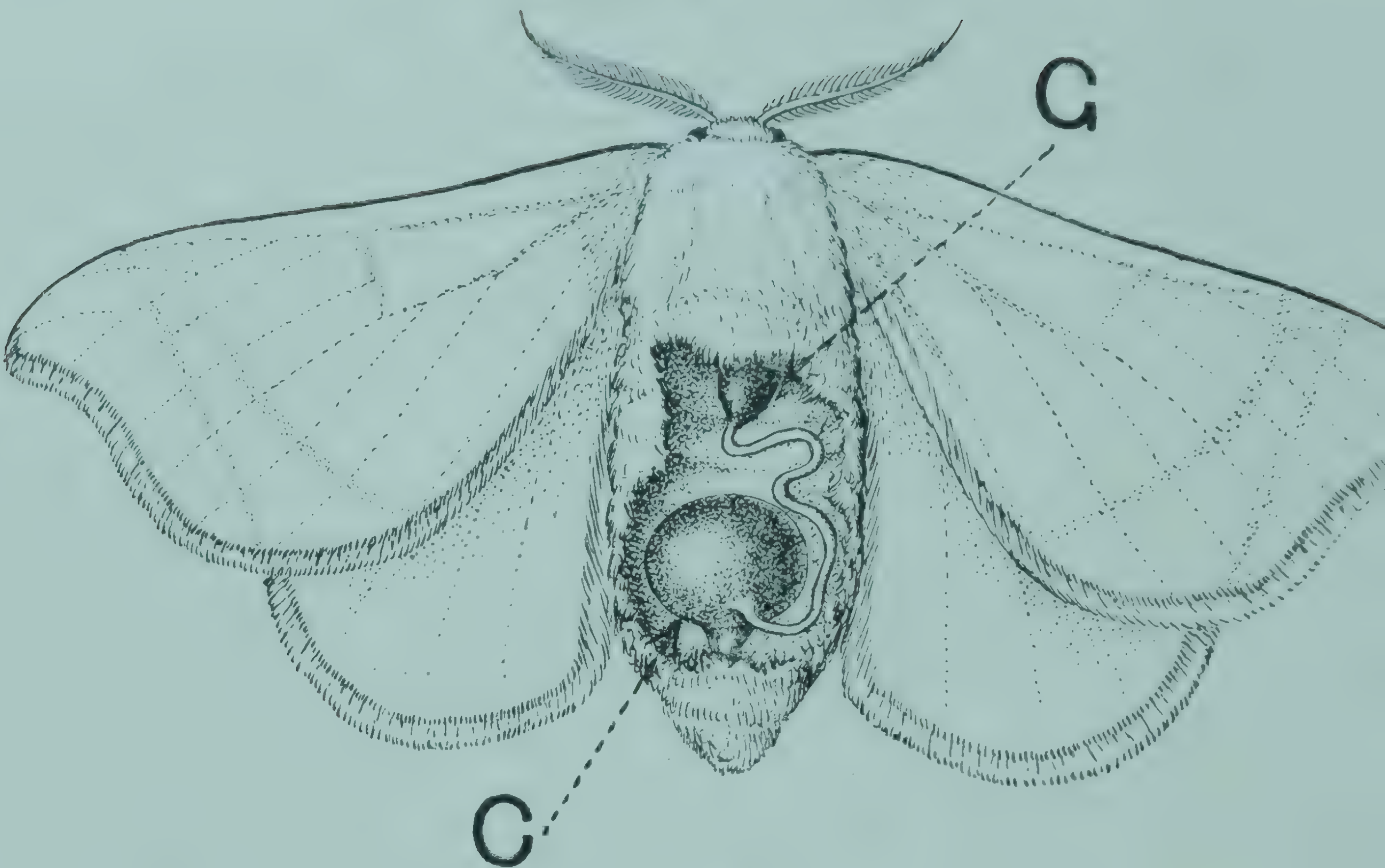

Fig. 1.

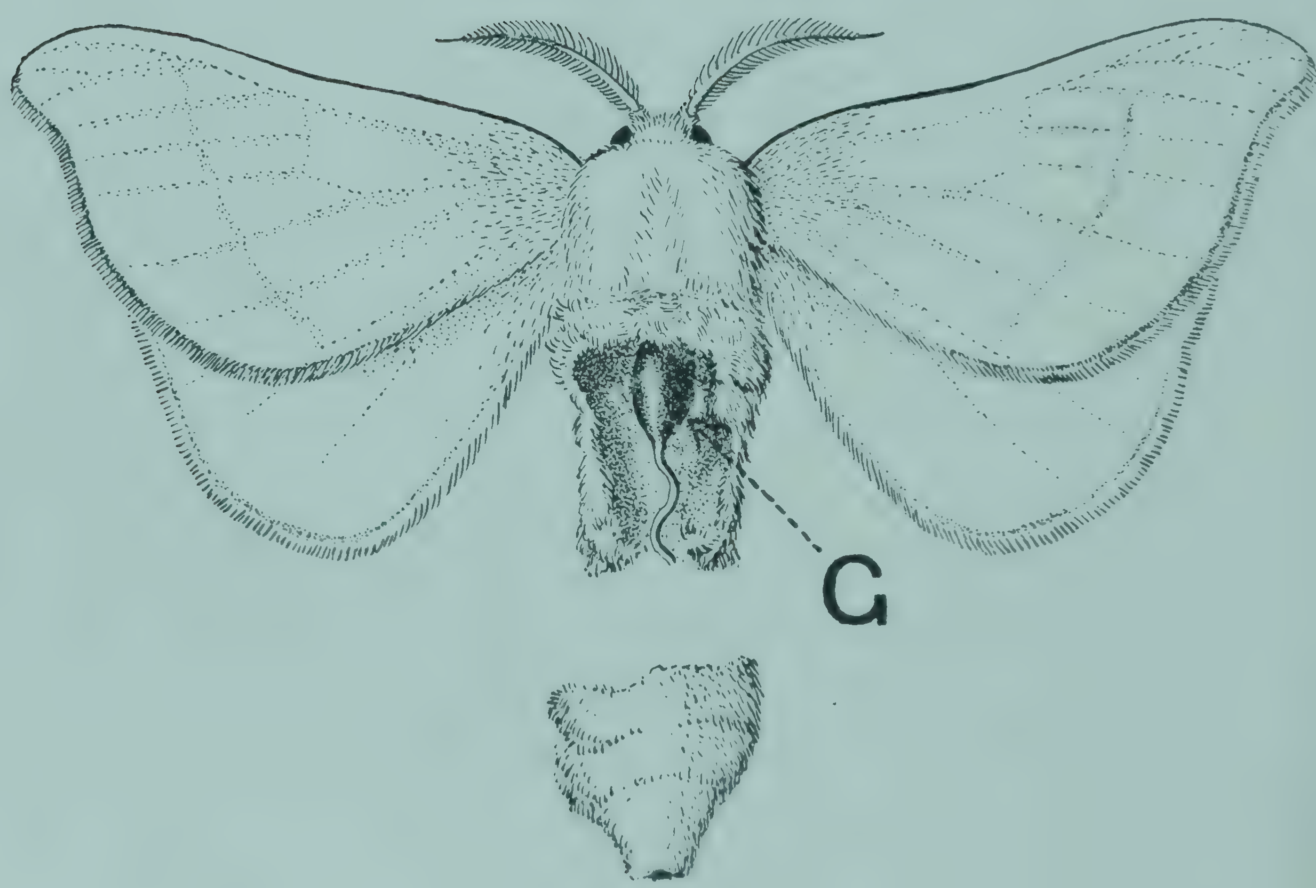

Fig. 2.
Gut (G) and Colon (C) of Moth.

effect of this difference is to make it necessary in India to carry out the examination of the parent moth within the comparatively limited period of one week from the date of laying, whereas in Europe this period can be, and generally is, extended for convenience sake to some weeks or months. Now it has been found in India that a considerable percentage of worms derived from moths examined and passed as disease-free develop pebrine notwithstanding such examination, and the first conclusion arrived at was that the examination was defective because of the assumption that if disease was present it would be found by the very rough method in vogue ; this method practically assumes that the pebrine bodies if present at all will be so universally distributed throughout the body of the moth that some of them are certain to be found in the minute fraction of the whole represented by the field of view of the microscope. Investigation showed that under the conditions obtaining in India this assumption was unwarranted ; numerous cases occurred in which no pebrine bodies were found by the ordinary method of examination whereas they were readily detectable by the modified one which I wish to recommend ; moreover the disease showed itself in the progeny although the parent moths would have been passed as disease-free by any user of the routine method. The Indian method of examination also differs from the European not only in point of time elapsing between laying and examination, but also in the method of taking the material for examination. In Europe the body of the moth when examined some months after death is perfectly dry, and water is added to the crushed tissues for examination. In India the fresh body of the moth contains body fluids of various kinds and the technique usually adopted, simply crushing the body and smearing the exudate upon a slide, results in the major portion of the fluid examined being derived from a single organ, the Colon (Plate I, Fig. 1 C), so that the result of the examination depends largely upon the invasion of the lumen of this part of the a imentary tract by the parasite. I have found by examination of several hundreds of specimens that pebrine bodies may be almost absent from the liquid from this organ although present in the ovaries and other parts of the body, and this fact would account for the failure of this method of examination to detect the disease.

By examination of large numbers of pebrinized moths it was found possible to ascertain in what part of the body the pebrine corpuscles first seem to appear, or at least in what part they are invariably found if any are found at all. This part of the moth is the gut or chyle stomach, readily accessible by mere separation of the lower portion of the abdomen, with a needle, forceps, or other instrument leaving the dark canal of the gut exposed as shown in

Plate I, Fig. 2 G. A minute portion of the gut removed on the needle and rubbed with water on the slide will show the presence of pebrine bodies if they occur in the body of the moth in sufficient number to be detected by rough microscopic examination.

It may be of interest here to give the probable reasons why the presence of pebrine is more likely to be detected by examination of the tissues of the gut than of any other part. Infection, except hereditary infection, takes place through the food and so through the alimentary canal and particularly in the gut ; the infecting bodies find their way from the gut through its walls into the cells (epithelial) which form the lining layer of the gut and whose function is to secrete digestive fluids. In these cells then actual invasion of the tissues of the host first takes place and from them the infection spreads by movement and multiplication of the invading parasites ; it follows that as the parasite grows by feeding on the tissues of its host the food supply afforded by the latter must fail earliest at that point which was first invaded, and as failure of nutriment results in the passage of the protozoon into the resting or spore condition, and it is in this condition that the parasite is readily recognizable under microscopic examination, it will readily be understood why the tissues of the gut, where infection first took place, present the most likely point for discovering its presence, and although the gut in the moth is practically functionless it is known that the elements from which it is built up in the reconstructive process during the pupal stage are identical with those of the larva from which they are derived.

Now in the case of dried bodies of moths examined some weeks after death the condition of affairs appears to be different, for in no case were pebrine corpuscles found in the gut and not in other organs ; in fact it may be said that when pebrine was found in any part of the dried body it was discoverable in practically every part ; the apparent conclusion would be that the pebrine parasite continued to multiply in the body of the moth after death until the whole of the tissues were invaded ; in view of the rapid drying up of the latter this seemed a difficult theory to accept and further investigation has now led me to advance an alternative one.

The life cycle of the pebrine parasite, *Nosema bombycis*, as worked out by Stempel, and of other similar Microsporidia such as *Nosema apis* (Fantham and Porter) and *Nosema culicis* (Korke) includes transition through an actively multiplying stage (merogony) to the resting or spore stage (sporogony).

During the first stage the organism would be recognizable only with difficulty under the microscope under the conditions in which examination is ordinarily carried out ; in the second or spore stage it is readily

Showing (small) active multiplying forms and (large) resting spores,
in gut wall of moth.

recognized by reason of the thick refractile envelope or sporocyst characteristic of the resting condition. Now the function of the spore is to carry the parasite through conditions unfavourable to its active life, such conditions including absence of suitable nourishment and of moisture ; when the supply of food for the parasite is exhausted by the penetration of the latter to all the tissues of the host, or by the drying up of the dead body of the moth, the protozoon passes into the resting or spore stage simultaneously becoming recognizable under ordinary examination. (Plate II.) For this reason a moth which, although full of pebrine, might be passed as disease-free by the routine method of examination a few days after laying, would, if kept for some weeks, appear obviously pebrinized. This fact will explain the greatly increased probability of detecting pebrine by the Pasteur method in Europe working with univoltine races as compared with the chance of doing so with the method as used in Bengal with multivoltine varieties. At the same time it must be pointed out that even in Europe the detection of pebrine depends upon the presence in the moth of a sufficiently large number of parasites to ensure the presence of some of them in the field of the microscope, and there can be no doubt that the failure of the Pasteur method to eliminate the disease after 40 years' trial must be largely due to the escape of those individual cases in which sufficient parasites were present to infect the ovaries and consequently the eggs, but not to allow of detection by the routine method of examination. In Europe, however, the percentage affected is so small that no demand appears to exist for any improvement in the method, and in fact the use of the so called "industrial" seed derived from moths of which only a certain percentage have been examined, is evidence of the absence of such a demand. Should conditions ever require more stringent control this could be effected by the use of the more particular method of examination which I have described above, the adoption of which I consider necessary in India for the selection of disease-free seed in the rearing of multivoltine races of the mulberry silkworm.

PUSA,

30th April, 1917.

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Experiments with Emulsions for protecting Camels against the attacks of Blood-sucking Flies.

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IT is a well known fact that surra is spread from camel to camel by blood-sucking flies. If healthy camels have to pass through an area where surra is known to exist and blood-sucking flies are prevalent the chances of healthy camels marching through the area without contracting the disease are very remote. If, however, the healthy camels can be protected against the attacks of blood-sucking flies they would be able to march through the area without fear of contracting the disease. The following experiments were carried out to determine the efficacy of various preparations for protecting camels against blood-sucking flies.

The following emulsions were used :—

I. Kerosine oil emulsion.
II. Tara-mira (*Eruca sativa*) oil emulsion.
III. An emulsion prepared by Mr. Warde of the Forest Department.
IV. Asafœtida solution.
V. Chirpine oil emulsion.
VI. Creosol emulsion.
VII. Jensen's emulsion.
VIII. Citronella oil.
IX. Aniseed oil.
X. Cod liver oil.
XI. Castor oil.

I. Kerosine oil emulsion.

Six camels were used in the experiments, four being sprayed with the emulsion and two acting as controls. One control was kept 50 yards away from the other camels and the other control was kept in the centre of the sprayed camels, each of these being tied about five yards distant from one another, all close to a permanent pond in a grazing ground in the plains, where Tabanidæ were found to be prevalent.

The emulsion was made by dissolving soap in water, slowly adding the kerosine oil, stirring briskly the whole time. It was applied to the camel by means of a spray pump.

Experiment 1.

Soap	1 lb.
Kerosine oil	20 oz.
Water	1 gallon.

Each camel (except the two controls) was sprayed with two pints of the emulsion. Before the emulsion was sprayed on to the camels *Stomoxys* were numerous on all the camels. At the time of spraying the camels the *Stomoxys* at once left the camels but reappeared in 25 minutes after the application of the emulsion.

Tabanidæ appeared on the sprayed camels about 3 hours after they were sprayed. They appeared at the same time on the two control camels.

Result. Stomoxys were only kept off for 25 minutes. Tabanidæ appeared on the sprayed camels and controls at the same time ; this emulsion did not prevent Tabanidæ from biting three hours after the application.

Experiment 2.

The amount of the emulsion applied was increased by one pint, each camel being sprayed with 3 pints. The increased amount sprayed on gave no better results. *Stomoxys* appeared on the camels 25-30 minutes after the application of the emulsion. Tabanidæ appeared on the sprayed and control camels at the same time, about 3 hours after the application of the emulsion.

Result.

(1) *Stomoxys* were kept off for 25 minutes.

(2) Three hours after the application Tabanidæ were not prevented from biting.

(3) During the night mosquitos worried the camels greatly and there was no difference between the control and the sprayed camels.

II. Tara-mira (*Eruca sativa*) oil emulsion.

Experiment 1.

The emulsion consisted of—

Soap	1 lb.
Tara-mira oil	20 oz.
Water	1 gallon.

Three pints of the emulsion were sprayed on each camel. *Stomoxys* disappeared on application of the emulsion but in 25-30 minutes were again seen on the sprayed camels. Tabanidæ appeared at the same time on the sprayed and control camels about 3 hours after the application of the emulsion.

Result.

(1) *Stomoxys* were kept off 25-30 minutes.

(2) Three hours after the application Tabanidæ were not prevented from biting.

(3) The sprayed camels were worried at night by mosquitos to the same extent as the control camels.

Experiment 2.

The above experiment was repeated and the same results obtained.

III. Emulsion prepared by Mr. Warde of the Forest Department.

Experiment 1.

This anti-fly emulsion was submitted to me for trial by Mr. Warde. The preparation has a very pungent odour and would appear to contain amongst other things eucalyptus oil and turpentine. Only one pint was sent; the amount was sprayed on a camel but was insufficient to spray the camel all over thoroughly. *Stomoxys*, which were numerous on the camel before spraying commenced, on spraying the camel left at once and did not return for an hour. Its efficacy with regard to *Stomoxys* was, therefore, double that of the kerosine oil and *tara-mira* oil emulsions. Tabanidæ appeared on the controls and the camel sprayed with this preparation at the same time, namely, 3-4 hours after the application.

Result.

(1) *Stomoxys* were prevented from biting for one hour.

(2) Tabanidæ were not prevented from attacking the camel 3-4 hours after the application.

Experiment 2.

Three pints were obtained from Mr. Warde and sprayed on a camel. At a distance of four yards from the camel the odour of the preparation could be distinctly smelt. Tabanidæ were seen on the sprayed camel at the same time as on the control camels, namely, 3 hours after the application. Although it had very little effect against the flies, its effect was very marked on the camel. The camel was restless all day, and was off his feed; next morning it was noticed that the skin was slightly blistered. I mentioned the effect of his preparation on the camel to Mr. Warde, and he stated that once when he had applied it to some of his hens for ticks they had died shortly afterwards; he had however not attributed at that time the death of his hens to the solution, but he was now convinced that the solution was the cause of death.

Result.

(1) Tabanidæ were not prevented from biting 3 hours after the application of the preparation.

(2) The skin of the camel was slightly blistered.

(3) The preparation made the camel restless and put him off his feed.

IV. Asafoetida solution.

Experiment 1.

The strength of the solution was 1 of asafœtida to 8 of water. Three pints were sprayed on each camel. *Stomoxys* were seen on the sprayed camels a few minutes after the application of the solution. Tabanidæ appeared on the sprayed camels at the same time as on the controls.

Result. The solution had no repellent action against *Stomoxys* and Tabanidæ.

V. Chirpine oil emulsion.

Experiment 1.

The emulsion consisted of—

Soap	1 lb.
Chirpine oil	20 oz.
Water	1 gallon.

Four pints of the emulsion were sprayed on each camel when *Stomoxys* were numerous on them. The *Stomoxys* at once left the sprayed camels, though they continued to be seen on the controls. Tabanidæ appeared on the control camels 2 hours before they appeared on the sprayed camels.

Result. This emulsion prevented Tabanidæ from attacking the camel for two hours.

Experiment 2.

Experiment 1 was repeated in the hills (altitude 6,000 ft.) on some camels that were placed in a thick jungle in which Tabanidæ were very numerous. The trees afforded a great deal of protection from the sun, consequently the emulsion did not dry nearly so quickly as it did in Experiment 1, which was carried out in the plains in a place where the trees were small and gave very little protection against the sun. In the hills the Tabanidæ appeared on the control camels 4-5 hours before they appeared on the sprayed camels.

Result.

(1) Tabanidæ were prevented from biting for 4-5 hours.

(2) The efficacy of the emulsion was greater when the camels were protected from the sun and the temperature was lower, due to the emulsion not drying so quickly.

Experiment 3.

In this experiment a stronger emulsion was used and consisted of—

Chirpine oil	40 oz.
Soap	1 lb.
Water	1 gallon.

Four pints of this emulsion were sprayed on the camels.

Result.

(1) Tabanidæ appeared on the control camels three hours before they appeared on the sprayed camels.

(2) With this strength of emulsion there is a tendency to blister when the camels are not protected from the sun.

VI. Creosol emulsion.

This emulsion was suggested by Major Rudd, A.V.C., and was composed of—

Creosol	1 oz.
Pix Liquida	2 oz.
Soft Soap	8 oz.
Water	3 pints.

The amount Major Rudd recommends to be used is 3 pints.

Experiment 1.

Six camels were sprayed with 3 pints of the emulsion at 5 P.M. These camels were placed in the shade of trees near water, one unsprayed camel to act as control, being placed in close proximity to them. They were kept under observation for two hours. Two Tabanidæ were caught on the control (unsprayed) camels but none were found on the sprayed camels. The fact that only two Tabanidæ were seen on the unsprayed camel, showed that only few Tabanidæ were about at the time; on the other hand it should be noted that the only Tabanidæ seen in two hours were on the unsprayed camel, none being found on the sprayed.

Experiment 2.

The six sprayed camels and the one unsprayed camel were examined next morning between 6 A.M. and 7 A.M. (*i.e.*, about 13 hours after being sprayed) for Tabanidæ. A large number of Tabanidæ were found on the sprayed and also on the control (unsprayed) camel. Tabanidæ attacked the sprayed and unsprayed equally.

Experiment 3.

The six camels were again sprayed at 7·30 A.M. and were placed in the sun in close proximity to the unsprayed camel and though Tabanidæ flew round the sprayed camels they did not settle and suck blood till thirty minutes had elapsed after the application of the emulsion.

Result.

(1) Three pints of this emulsion are scarcely sufficient to spray a camel thoroughly.

(2) After 12-13 hours the emulsion did not prevent the Tabanidæ from biting.

(3) If the camels were sprayed and kept in the sun the emulsion prevented Tabanidæ from biting for ½ hour only.

(4) As soon as the emulsion has dried on the skin it does not appear to have the slightest efficacy against the attacks of Tabanidæ.

VII. Jensen's emulsion.

This emulsion is composed of—

Kerosine oil	1 gallon.
Powdered naphthaline . . .	4 oz.
Soap	1 lb.
Water	4 gallons.

Experiment 1.

One application of this emulsion is said to protect cows against *Stomoxys calcitrans* and *Lyperosia irritans* for a week. Five pints of this solution were sprayed on two camels at 7 A.M. and one unsprayed camel acted as control. The three camels were tied at a short distance from one another, near a pond in a *rakh* (grove), where Tabanidæ were known to be prevalent. Between 4 P.M. and 7 P.M. Tabanidæ and *Stomoxys* were observed on the control but none were seen on the sprayed camels. At 8 A.M. on the following day one Tabanus was observed on one of the sprayed camels. Between 4 P.M. and 7 P.M. numerous Tabanidæ were present on both the sprayed and unsprayed camels.

Remarks.

(1) At the time when these experiments were carried out, camels had little or no hair and the sun was very powerful.

(2) The emulsion caused severe blistering of the skin.

Result.

(1) This emulsion prevents Tabanidæ from biting for 12 hours.

(2) The emulsion cannot be recommended for camels as it causes severe blistering of the skin.

VIII. Citronella oil.

Experiment 1.

Three camels were used in this experiment, one being sprayed with 3 pints of the oil and the remaining two acting as controls. At 5-30 P.M.

when Tabanidæ and *Stomoxys* were observed on all three camels three pints of the oil were sprayed on one camel. From 5-30 P.M. to 7-30 P.M. no Tabanidæ or *Stomoxys* were seen on the sprayed camel but they continued to bite the two unsprayed. After 7-30 P.M. no flies were observed on the controls. On the following day Tabanidæ appeared on the sprayed and unsprayed at about the same time (12 noon).

Result.

(1) Citronella oil prevents Tabanidæ and *Stomoxys* from biting for a few hours.

(2) It has no repellent action after 17 hours.

IX. Cod liver oil.

Experiment 1.

Three camels were used in this experiment, one being smeared with oil and two being left unsmeared to act as controls. The three camels were tied at a short distance from one another and 17 oz. of oil was smeared on one camel by means of a rag. A few minutes after the application of the oil *Stomoxys* were seen on the camel, the oil had no repellent action whatever against *Stomoxys*.

Three hours after the application of the oil Tabanidæ were observed on the smeared and unsmeared camels.

Result. Cod liver oil has no repellent action against Tabanidæ and *Stomoxys*.

X. Aniseed oil.

Experiment 1.

Three camels were used, one being sprayed with one pint of oil, the remaining two acting as controls. After the application of the oil, the camel became restless but after about one hour the irritating effect of the oil passed off. Two and a half hours after the application of the oil Tabanidæ were seen to suck blood ; Tabanidæ were noticed about the same time on the controls. *Stomoxys* were observed on the controls practically the whole time but were only observed to settle on the sprayed camel 3 hours after the application of the oil.

Result.

(1) Aniseed oil has no repellent action against Tabanidæ $2\frac{1}{2}$ hours after application.

(2) It has a slight repellent action against *Stomoxys*.

(3) The application of only one pint causes great restlessness in the camel.

XI. Castor oil.

Experiment 1.

One pint of castor oil was smeared on one camel, 3 unsmeared camels acting as controls.

Thirty-five minutes after the application of the oil Tabanidæ were seen on the controls. Fifty minutes after the application of the oil Tabanidæ approached the smeared camel but did not settle.

One hour and fifteen minutes after the application of the oil Tabanidæ were seen sucking blood on the smeared camel. *Stomoxys* were observed on the smeared camel twenty minutes after the application of the oil.

Result. One pint of castor oil smeared on a camel has practically no repellent effect against Tabanidæ and *Stomoxys*.

Experiment 2.

One camel was smeared with 3 pints of castor oil and five unsmeared camels acted as controls. The oil was not applied till Tabanidæ were seen on the camels.

The oil was applied to one camel at 9-30 A.M.

From 9-30 A.M. to 10-30 A.M. no Tabanidæ were seen on the smeared camel though Tabanidæ and *Stomoxys* were numerous on the controls. During this time Tabanidæ approached the smeared camel but flew away without biting.

At 10-45 A.M. Tabanidæ were seen on the smeared camel and for the next hour Tabanidæ attacked the smeared camel to the same extent as the controls.

Result. Three pints of castor oil smeared on a camel prevents Tabanidæ from biting for only one hour.

Experiment 3.

One camel was smeared with 4 pints of oil, two unsmeared camels acting as controls. The oil was applied at 8-30 A.M.

1st day. At 9-50 A.M. *Stomoxys* appeared on the two controls and were present nearly the whole day till evening. None, however, settled on the smeared camel ; they frequently approached the smeared camel but did not settle.

At 11 A.M. Tabanidæ appeared on the controls and except from 2-30 P.M. to 4-30 P.M. were seen on the two control camels till 7 P.M. No Tabanidæ, however, attacked the smeared camel ; they frequently approached but did not settle except once when a Tabanus settled for an instant but flew away without sucking.

2nd day. Stomoxys were present more or less the whole day on the controls but though they approached the smeared camel they did not settle. From 11-40 A.M. to 7 P.M. Tabanidæ were frequently seen on the two controls but did not attack the smeared camel : on three occasions Tabanidæ settled on the smeared camel for an instant but immediately flew away without sucking.

3rd day. From 8 A.M. to 6-30 P.M. *Stomoxys* were frequently seen on the two control camels. A few *Stomoxys* settled for a short time on the smeared camel, but flew away without sucking. Tabanidæ were numerous on both controls at various times during the day but none were observed on the smeared camel.

4th day. Stomoxys were observed on the two controls and on the smeared camel ; Tabanidæ were numerous on the controls and a few Tabanidæ were seen on the smeared camel.

5th day. Stomoxys and *Lyperosia* were observed on the two controls and on the smeared camel. Tabanidæ were numerous on the two controls and were also observed on the smeared camel but not nearly to the same extent as on the unsmeared camels.

6th day. Stomoxys were observed on the two controls and the smeared camel. Tabanidæ were also observed but were more numerous on the unsmeared than on the smeared camel.

Remarks. It was thought that castor oil might have a harmful effect upon the skin, as it is liable when exposed to the air to thicken and form a varnish-like film ; no harmful effect, however, was observed.

Result.

(1) Four pints of castor oil when smeared on a camel prevents Tabanidæ and *Stomoxys* from biting for three days.

(2) From the 4th to the 6th day Tabanidæ were less numerous on the smeared camel than on the unsmeared.

Experiment 4.

As the result obtained by smearing with 3 pints of castor oil was very different from the result obtained by smearing with 4 pints it was decided to repeat the experiment with 4 pints.

One camel was smeared with 4 pints of castor oil at 9-30 A.M. and one unsmeared camel acted as control. The camels were tied at a short distance from one another.

1st day. *Stomoxys* were observed on the unsmeared camel from 9-30 A.M. till evening; twenty-three Tabanidæ were counted on the unsmeared camel during the day and two Tabanidæ settled on the smeared camel but did not suck any blood. A few *Stomoxys* settled on the smeared camel but did not remain for any length of time.

2nd day. Tabanidæ were numerous on the unsmeared camel and on the smeared camel, a few Tabanidæ settled but flew away without biting. *Stomoxys* settled on the smeared camel but no *Stomoxys* were observed to bite.

3rd day. *Stomoxys* were observed on the control and several Tabanidæ attacked the control. On the smeared camel *Stomoxys* were numerous but none was observed to suck. Several Tabanidæ settled on the smeared camel but none was seen to suck.

4th day. Flies were not numerous; they attacked the smeared and unsmeared camels to the same extent.

Result. Four pints of castor oil prevented Tabanidæ and *Stomoxys* from biting for 3 days. *Stomoxys* and Tabanidæ were observed to settle on the smeared camel a few hours after the application of the oil; they, however, did not bite.

Remarks. The result obtained with 4 pints was very different from that obtained with 3 pints, but it is improbable that the extra pint of oil could make such a difference. At the time of year that the experiments were carried out, the quantity of hair on camels varies greatly. The camel that was smeared with 3 pints had practically no hair, whereas both camels that were smeared with 4 pints had a fair quantity of hair. The matting of the hair by the oil might explain why Tabanidæ did not attack those parts where there is hair, but it does not explain why Tabanidæ did not attack the camels smeared with 4 pints, on the sheath and inside of the thighs where there is never any hair on camels.

Conclusions.

Of the preparations used the only one that prevented Tabanidæ from attacking for any length of time was castor oil, but it cannot be recommended on account of the cost. None of the other preparations tried are of any practical value. As soon as the emulsions dry they have no repellent action against the flies.

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Some Camel-feeding Experiments.

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OUR knowledge regarding the quantity of fodder that a camel requires is very limited, and no experiments have, so far as I am aware, been carried out to determine the quantity of fodder that a camel requires to keep him in condition. Requests having been frequently made by the military authorities for information regarding the quantity of fodder that should be given to camels, it was decided to carry out some feeding experiments on these animals.

The only camels available for the purpose were medium-sized camels suffering from surra (7-14 years old). It would have been much more satisfactory had it been possible to carry out the experiments with non-surra-infected camels, but this it was not possible to arrange.

The camel is an animal that can be trained to eat almost anything, and the fodder on which he feeds varies greatly in different parts of the world. The Punjabi camelmen prefer browsing to stall-feeding, and undoubtedly the camel thrives well if sufficient time is allowed for browsing, and the browsing is of good quality. When the browsing is poor or sufficient time is not available, fodder such as *missa bhusa* (pea straw), *moth bhusa* (*Phaseolus aconitifolius* straw), and *mung bhusa* (*Phaseolus mungo* straw), and, when in the season, green *tara-mira* (*Eruca sativa*), green *moth* (*Phaseolus aconitifolius*) and green gram are fed to the camels. As a rule the camelman does not feed gram to his camels, being unable to afford it. *Chitta bhusa* (wheat straw) and *phaliyat* (*Eruca sativa* stalks) are occasionally fed. Camelmen however do not like *chitta bhusa* (wheat straw) as a camel fodder and *phaliyat* (*Eruca sativa* stalks) has probably little nutritive value. Without doubt a camel thrives best on fodder and browsing that he has been accustomed to. A camel brought to a district, the browsing in which differs from that to which he has been accustomed or when stall-fed on fodder that he has not been used to, will fall off in condition ; but if he is carefully looked after and only lightly loaded to start with, he quickly becomes accustomed to the change and will rapidly regain his condition.

Experiments regarding the quantity of fodder a camel will eat were carried out with the following :—

(1) Gram and *missa bhusa.*
(2) *Missa bhusa* without grain.
(3) Gram and *moth bhusa.*
(4) *Moth bhusa* without grain.
(5) Barley, turnips and *moth bhusa.*
(6) Gram and green *tara-mira.*
(7) Green *sarson* (Indian colza).
(8) Oat hay and ordinary hay.

The camels got poor browsing during the day : the fodder was given in the evening at about 5 P.M.

12 LB. OF GRAM AND MISSA BHUSA.

Amount (in lb.) eaten by each camel, G represents gram and B missa bhusa.

Day	Camel No. 1514		Camel No. 33		Camel No. 658		Camel No. 714		Camel No. 773		Camel No. 83		Camel No. 393		Camel No. 48	
	G	B	G	B	G	B	G	B	G	B	G	B	G	B	G	B
1st . . .	12	18	12	8	12	14	12	15	12	17	12	18	12	26	12	12
2nd . . .	12	28	12	22	12	19	12	30	12	24	12	15	12	12	12	10
3rd . . .	12	27	12	22	12	22	12	22	12	18	12	27	12	22	12	15
4th . . .	12	28	12	22	12	20	12	17	12	26	12	12	12	18	12	16
5th . . .	12	31	12	29	12	20	12	30	12	27	12	11	12	20	12	17
6th . . .	12	31	12	30	12	25	12	35	12	31	12	11	12	17	12	8
AVERAGE . .	12	27·1	12	22·1	12	20·0	12	24·8	12	23·8	12	15·6	12	19·1	12	13·

Average = 12 lb. gram and 20·6 lb. *missa bhusa.*

The gram was fed first and 40 lb. of *missa bhusa* was given to each camel ; the amount left over next morning was weighed.

6 LB. GRAM AND MISSA BHUSA.

Amount (in lb.) eaten by each camel, G represents gram and B missa bhusa.

Day	Camel No. 1987		Camel No. 2921		Camel No. 658		Camel No. 714		Camel No. 1959		Camel No. 1759		Camel No. 894		Camel No. 1314	
	G	B.	G	B	G	B	G	B	G	B	G	B	G	B	G	B
1st . . .	6	20	6	26	6	23	6	22	6	22	6	30	6	28	6	28
2nd . . .	6	12	6	23	6	20	6	22	6	20	6	27	6	27	6	25
3rd . . .	6	18	6	20	6	30	6	30	6	25	6	30	6	32	6	30
4th . . .	6	14	6	23	6	30	6	21	6	20	6	25	6	27	6	27
5th . . .	6	20	6	24	6	24	6	24	6	19	6	24	6	23	6	16
6th . . .	6	17	6	27	6	22	6	20	6	20	6	23	6	24	6	25
7th . . .	6	23	6	24	6	30	6	30	6	20	6	26	6	27	6	20
8th . . .	6	20	6	26	6	22	6	30	6	21	6	25	6	25	6	15
9th . . .	6	18	6	21	6	30	6	29	6	18	6	27	6	23	6	27
10th . . .	6	20	6	25	6	30	6	31	6	13	6	26	6	23	6	27
11th . . .	6	18	6	25	6	18	6	27	6	17	6	30	6	28	6	14
12th . . .	6	19	6	20	6	30	6	22	6	21	6	30	6	26	6	20
13th . . .	6	19	6	22	6	35	6	26	6	23	6	27	6	25	6	18
14th . . .	6	17	6	20	6	31	6	17	6	20	6	27	6	25	6	22
15th . . .	6	18	6	27	6	30	6	24	6	15	6	25	6	25	6	20
16th . . .	6	18	6	12	6	17	6	30	6	13	6	20	6	20	6	30
17th . . .	6	17	6	20	6	29	6	28	6	18	6	22	6	22	6	24
18th . . .	6	17	6	23	6	31	6	35	6	19	6	22	6	25	6	25
19th . . .	6	16	6	22	6	20	6	26	6	22	6	25	6	16	6	15
20th . . .	6	25	6	26	6	19	6	30	6	25	6	29	6	20	6	30
21st . . .	6	20	6	22	6	25	6	30	6	10	6	20	6	24	6	27
22nd . . .	6	16	6	18	6	19	6	26	6	21	6	20	6	19	6	34
23rd . . .	6	17	6	25	6	30	6	20	6	22	6	28	6	24	6	16
24th . . .	6	22	6	20	6	27	6	28	6	26	6	30	6	22	6	24
25th . . .	6	21	6	23	6	22	6	25	6	23	6	24	6	22	6	20
AVERAGE . .	6	18·4	6	22·5	6	25·7	6	26·1	6	19·7	6	25·6	6	24·0	6	23·

Average = 6 lb. gram, 23·1 lb. *missa bhusa.*

The gram was fed first and 40 lb. of *missa bhusa* was given to each camel; the amount left over next morning was weighed.

MISSA BHUSA.

Amount (in lb.) eaten by each camel.

Day	CAMEL No. 658	CAMEL No. 1987	CAMEL No. 1759	CAMEL No. 714	CAMEL No. 2921	CAMEL No. 894
1st . . .	27	26	33	30	23	35
2nd . . .	22	22	30	28	20	22
3rd . . .	30	24	26	26	20	28
4th . . .	26	20	25	21	22	20
5th . . .	28	26	28	16	25	22
6th . . .	26	18	32	18	27	28
7th . . .	22	22	23	16	23	24
8th . . .	22	22	15	22	20	25
9th . .	30	32	32	20	32	39
10th . . .	31	24	28	28	23	24
AVERAGE .	26·4	23·6	27·2	22·5	23·5	26·7

Average = 24·9 lb. *missa bhusa.*

40 lb. of *missa bhusa* was given to each camel in the evening and the amount left over next morning was weighed.

4 LB. GRAM AND MISSA BHUSA, 2 YEAR OLD CAMELS.

Amount (in lb.) eaten by each camel, G represents gram and B missa bhusa.

Day	CAMEL No. 11 (MALE)		CAMEL No. 12 (MALE)		CAMEL No. 13 (FEMALE)	
	G	B	G	B	G	B
1st . . .	4	12	4	11	4	6
2nd . . .	4	12	4	14	4	12
3rd . . .	4	12	4	17	4	14
4th . . .	4	12	4	16	4	12
5th . . .	4	20	4	12	4	10
6th . . .	4	21	4	17	4	13
7th . . .	4	22	4	18	4	18
8th . . .	4	22	4	18	4	12
9th . . .	4	17	4	15	4	13
10th . . .	4	15	4	14	4	13
11th . . .	4	16	4	14	4	17
12th . . .	4	21	4	13	4	10
AVERAGE .	4	16·8	4	14·9	4	12·5

Average = 4 lb. gram and 14·7 lb. *missa bhusa.*

The gram was fed first and 30 lb. of *missa bhusa* was given to each camel ; the amount left over next morning was weighed.

6 LB. GRAM AND MOTH BHUSA.

Amount (in lb.) eaten by each camel, G represents gram and B moth bhusa.

Day	Camel No. 1		Camel No. 2		Camel No. 3		Camel No. 4		Camel No. 5		Camel No. 6	
	G	B	G	B	G	B	G	B	G	B	G	B
1st	6	20	6	28	6	19	6	20	6	18	6	22
2nd	6	19	6	30	6	20	6	20	6	24	6	30
3rd	6	20	6	28	6	29	6	30	6	30	6	40
4th	6	20	6	30	6	30	6	35	6	27	6	37
5th	6	21	6	34	6	27	6	37	6	30	6	10
6th	6	23	6	30	6	20	6	36	6	35	6	20
7th	6	23	6	30	6	23	6	36	6	33	6	20
8th	6	24	6	32	6	21	6	38	6	25	6	30
Average	6	21·25	6	30·25	6	23·6	6	31·5	6	27·7	6	26·1

Average = 6 lb. gram and 26·7 lb. *moth bhusa*.

The gram was fed first and 50 lb. of *moth bhusa* was given to each camel ; the amount left over next morning was weighed.

Moth bhusa.

Amount (in lb.) eaten by each camel.

Day	Camel No. 33	Camel No. 1052	Camel No. 773	Camel No. 1361	Camel No. 157	Camel No. 1624	Camel No. 383	Camel No. 620	Camel No. 273
1st	20	18	20	15	39	22	20	22	15
2nd	24	23	20	12	25	20	20	20	20
3rd	25	20	20	20	27	20	25	36	25
4th	28	25	30	29	34	33	25	30	32
5th	29	24	35	29	40	40	40	40	37
6th	29	25	40	22	38	36	30	37	32
7th	25	33	38	27	28	35	40	32	33
8th	30	28	44	22	35	35	40	34	40
9th	35	27	37	30	28	41	35	32	30
10th	32	27	25	25	41	39	38	38	39
11th	25	30	27	28	37	42	39	45	40
Average	27·4	25·4	30·5	23·5	33·8	33·0	32·0	33·2	31·1

Average = 29·9 lb. *moth bhusa*.

50 lb. of *moth bhusa* was given to each camel and the amount left over next morning was weighed.

5 LB. BARLEY, TURNIPS AND MOTH BHUSA.

Amount (in lb.) eaten by each camel, B represents barley, T turnips and M. B. moth bhusa.

Day	Camel No. 1052			Camel No. 33			Camel No. 1314			Camel No. 1361			Camel No. 77		
	B	T	M. B	B	T	M. B	B	T	M. B	B	T	M. B	B	T	M.
1st	5	20	25	5	20	30	5	20	30	5	20	25	5	20	3
2nd	5	20	20	5	20	21	5	20	21	5	20	30	5	20	3
3rd	5	30	30	5	30	30	5	30	30	5	30	21	5	30	3
4th	5	30	28	5	30	28	5	30	15	5	30	40	5	30	3
5th	5	30	22	5	30	34	5	30	30	5	30	27	5	30	2
6th	5	30	20	5	30	25	5	30	25	5	30	25	5	30	1
AVERAGE	5	26·6	24·1	5	26·6	28·0	5	26·6	25·1	5	26·6	28·0	5	26·6	2

Average = 5 lb. barley, 26·6 lb. turnips and 26·4 lb. *moth bhusa.*

The barley was given first, then the turnips and then the *bhusa.* The camels did not relish the barley ; only 20 lb. of turnips were given to each camel the first two days. 50 lb. of *moth bhusa* was given to each camel and the amount left over next morning was weighed.

6 LB. GRAM AND GREEN TARA-MIRA.

Amount (in lb.) eaten by each camel, G represents gram and G T green tara-mira.

Day	Camel No. 714		Camel No. 1759		Camel No. 658		Camel No. 617		Camel No. 1653		Camel No. 606		Camel No. 894	
	G	G T	G	G T	G	G T	G	G T	G	G T	G	G T	G	G
1st	6	50	6	44	6	64	6	59	6	72	6	65	6	71
2nd	6	59	6	64	6	59	6	55	6	75	6	70	6	76
3rd	6	49	6	60	6	50	6	62	6	64	6	74	6	58
4th	6	74	6	58	6	74	6	48	6	68	6	62	6	70
5th	6	80	6	82	6	70	6	82	6	78	6	82	6	70
6th	6	46	6	82	6	61	6	79	6	69	6	74	6	72
7th	6	65	6	62	6	78	6	78	6	67	6	78	6	64
8th	6	74	6	65	6	73	6	73	6	75	6	74	6	74
9th	6	52	6	58	6	74	6	76	6	69	6	73	6	77
10th	6	59	6	60	6	68	6	60	6	72	6	72	6	72
11th	6	60	6	61	6	68	6	60	6	68	6	77	6	75
12th	6	59	6	62	6	51	6	79	6	69	6	80	6	86
13th	6	39	6	44	6	42	6	61	6	51	6	62	6	68
14th	6	51	6	53	6	35	6	68	6	57	6	69	6	73
15th	6	60	6	62	6	56	6	73	6	62	6	78	6	68
16th	6	61	6	58	6	63	6	69	6	71	6	70	6	59
17th	6	45	6	50	6	52	6	77	6	62	6	60	6	62
18th	6	52	6	59	6	70	6	78	6	66	6	72	6	64
19th	6	52	6	62	6	71	6	69	6	68	6	69	6	69
20th	6	70	6	56	6	69	6	75	6	72	6	72	6	78
21st	6	68	6	54	6	62	6	77	6	72	6	65	6	58
22nd	6	78	6	77	6	58	6	78	6	79	6	78	6	71
23rd	6	68	6	62	6	48	6	67	6	75	6	64	6	68
24th	6	72	6	66	6	67	6	78	6	77	6	72	6	76
AVERAGE	6	60·1	6	60·8	6	61·7	6	70·0	6	69·0	6	71·3	6	69·

Average = 6 lb. gram and 66·1 lb. green *tara-mira.*

The gram was fed first and 100 lb. of green *tara-mira* was then given to each camel and the amount left over next morning weighed.

GREEN SARSON.

Day	Amount eaten by each camel in lb.					Amount given to each camel in lb.
	No. 773	No. 1314	No. 1361	No. 1052	No. 33	
1st . . .	82	82	82	82	82	82
2nd . . .	100	100	100	100	100	100
3rd . . .	140	145	150	149	150	150
4th . . .	186	170	192	152	175	200
5th . . .	143	130	183	160	175	200
6th . . .	120	140	130	179	160	200
7th . . .	115	145	168	135	140	200
AVERAGE .	126·5	130·2	143·5	136·7	140·2	..

Average = 135·4 lb. green *sarson*.

On the 5th day the fæces became soft, like cow dung.

OAT HAY AND HAY.

Oat hay. Several camels were fed on oat hay. The oat hay was at first mixed with an equal quantity of *missa bhusa*, the quantity of the latter being daily reduced till finally only oat hay was given. The camels did not relish it, and the largest quantity eaten was 17 lb. The oat hay however was of poor quality.

Hay. Six camels were starved for one day and then fed on 6 lb. of gram and hay. The amount eaten is given in the following table. For the first three days they were given no grazing, for the remaining three days they were allowed to browse during the day.

4 LB. GRAM AND HAY.

G represents gram and H hay.

Day	Amount eaten in lb.													
	Amount given in lb.		Camel No. 658		Camel No. 1653		Camel No. 714		Camel No. 292		Camel No. 157		Camel No. 393	
	G	H	G	H	G	H	G	H	G	H	G	H	G	H
1st	6	20	6	15	6	16	6	20	6	0	6	20	6	20
2nd	6	35	6	20	6	18	6	31	6	19	6	24	6	15
3rd	6	35	6	20	6	23	6	16	6	25	6	15	6	10
4th	6	35	6	8	6	14	6	22	6	13	6	12	6	1
5th	6	35	6	15	6	10	6	8	6	20	6	20	6	13
6th	6	35	6	14	6	15	6	17	6	19	6	22	6	15
AVERAGE . .	..	..	6	15·3	6	16·0	6	19·0	6	16·0	6	18·8	6	12·3

Average = 6 lb. gram and 16·2 lb. hay.

MAXIMUM QUANTITY OF FODDER EATEN, IN ADDITION TO POOR BROWSING.

(1) 12 lb. gram and 35 lb. *missa bhusa.*
(2) 6 lb. gram and 35 lb. *missa bhusa.*
(3) 39 lb. *missa bhusa.*
(4) 2 lb. gram and 22 lb. *missa bhusa* (2 year old camels).
(5) 6 lb. gram and 40 lb. *moth bhusa.*
(6) 45 lb. *moth bhusa.*
(7) 5 lb. barley, 30 lb. turnips, and 40 lb. *moth bhusa.*
(8) 6 lb. gram and 86 lb. green *tara-mira.*
(9) 192 lb. green *sarson.*
(10) 6 lb. gram and 31 lb. hay.
(11) 17 lb. oat hay.

SUMMARY.

The average quantity of fodder eaten, in addition to poor browsing, was as follows :—

(1) 12 lb. gram+20·6 lb. *missa bhusa.*
(2) 6 lb. gram+23·1 lb. *missa bhusa.*
(3) 24·9 lb. *missa bhusa.*
(4) 4 lb. gram+14·7 lb. *missa bhusa* (2 year old camels).
(5) 6 lb. gram+26·7 lb. *moth bhusa.*
(6) 29·9 lb. *moth bhusa.*
(7) 5 lb. barley+26·6 lb. turnips +26·4 lb. *moth bhusa.*
(8) 6 lb. gram+66·1 lb. green *tara-mira.*
(9) 135·4 lb. green *sarson.*
(10) 6 lb. gram+16·2 lb. hay.

CONCLUSIONS.

Taking into consideration the fact that these experiments were carried out on camels suffering from surra and doing no work, it is probable that healthy camels on hard work would eat very much more. The experiments however show that the present government ration of 16 lb. of a mixture of wheat and *missa bhusa* per camel is insufficient.

Smuts of Jowar (*Sorghum*) in the Bombay Presidency.

[*Received for publication on 30th July, 1917.*]

The word Jowar as used in the Bombay Presidency indicates all the cultivated varieties of *Andropogon Sorghum* Brot. In India the crop occupies a third place among the cultivated crops, in acreage, covering an area of twenty-one million acres[1], while in the Bombay Presidency it ranks first, occupying more than eight million[2] acres. This area represents about one-sixth of the total cropped area of the Presidency and is more than one-third of the total area devoted to food grain crops. It is thus an important field crop in every part of the Presidency except in the Konkan, where, owing to excessive rainfall, it gives place to rice, and consequently occupies a small area, and in the Panch Mahals where maize (*Zea Mays*) is the staple. The reason why this crop is largely grown is because of its two-fold use as food and fodder. Its grain forms the chief article of diet of a large section of the population and its stems form first class fodder which is the main stay of the cattle. Any diseases affecting such an important and widely grown crop are, therefore, well worth studying.

The number of fungus diseases affecting this crop is large, but by far the most important of them from the economic point of view are those that cause the well-known smut disease. This disease has been long known to the cultivators under various names as *Kani* or *Kajali* in Marathi, *Kadige* in Kanarese, *Angario* in Gujarati, and *Kani* in Sindhi. It is also known in all other parts of India, especially in Madras, the Central Provinces, and Burma where it is very common, and throughout the world wherever varieties of *Andropogon Sorghum* are grown. Thus it is reported to occur on Durra or Kafir corn in Africa, Sorghum or Broom corn in Southern Europe and America, Guinea corn in the West Indies, and Sorghum or Amber cane in Australia. Investigators in these countries have discovered and described six or seven kinds of smuts on this crop. So far as India is concerned, however, only three of these smuts have previously been identified[3], though, as will be seen

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[1] *Statistical Abstract relating to British India from 1904-05 to 1913-14*, page 132.

[2] *Season and Crop Report of the Bombay Presidency* for the year 1915-1916, statement III.

[3] Sydow, H. V. P. and Butler, E. J. "Fungi Indiæ Orientalis" I. *Ann. Mycol.*, IV, 1906, pp. 425 and 427.

below, a fourth has now to be added. In Madras Barber[1] has published an account of the three commoner forms. But they have not received a thorough study either in their scientific aspects or in relation to practical agricultural applications.

There are four distinct smuts that occur on Jowar in this area ;—

1. *Grain Smut.* Here the normal grains in the head are transformed into enlarged, elongated, conical bodies protected for some time by a greyish membrane which on rupture exposes a dusty mass of black spores.

2. *Loose Smut.* This differs from the above in that the affected body has a fragile membrane which ruptures even before the head comes out. On exposure the head presents a dark sooty appearance.

3. *Long Smut.* Here the affected individual grains are much more elongated than either of the above two, up to as much as $1\frac{1}{2}$ inches in length.

4. *Whole-head Smut.* Here instead of individual grains being involved, the whole of the head, including the rachis, is converted into a fibrous spore mass.

Distribution.

Every district, in which Jowar is cultivated, suffers more or less severely from the disease. The virulence and distribution seem to depend upon (1) the character of the seed sown, (2) the locality and (3) the variety of the crop. Of these the first is the most important.

(1) *Character of the seed.* This expression is used to denote freedom or otherwise from contamination of seed with spores previous to sowing. It has been found that smut can be increased by mixing the spores with seeds before sowing. In the experiments conducted on the College Farm and the Ganeshkhind Botanical Gardens at Poona, it was observed that in the plots whose seed was dusted with spores smut was found in from 20 to 60 per cent. of the plants as compared with 6 to 8 per cent. in those plots where ordinary bazaar seed was used. It was also seen that in a few cases where the cultivators took care to select their seed only from disease-free fields, they got crops nearly free from smut. But in the majority of cases such care is not taken and the result is that smut is extremely common in all fields.

(2) *Locality.* In general, localities with high rainfall have more smut than those with low rainfall. Thus in the western parts of the Poona, Satara, Belgaum and Dharwar districts, which receive more

[1] Barber, C. A. " Diseases of *Andropogon Sorghum* in the Madras Presidency." *Bull. Dept. of Land Records and Agriculture, Madras,* II, No. 49, 1904, p. 275.

rain owing to their nearness to the Western Ghats, smut is found more abundantly than in the eastern parts of the same districts. Rao Saheb Malharrao Kulkarni, Divisional Inspector of Agriculture, Southern Division, who has done and is doing much work in the campaign of smut prevention, says in his report : "From personal observations of the disease in various parts of the Division, I think smut is more prevalent in parts where the rainfall is more severe. I also find that Kharif *jowar*[1] is more liable to smut than Rabi *jowar*[2], which also leads me to conclude that the greater rainfall in the Kharif season, than in the Rabi, is the cause of more disease in the former season."

In the Rabi tract smut is found to a small extent in the Gadag, Ron, and Navalgund Talukas of the Dharwar District, but is fairly common in the Bijapur, Ahmednagar, and Broach districts, while in the Sholapur District it developes into epidemics of varying severity in some place or other every year.

(3) *Variety of Crop.* It has been found that smut as a rule is more prevalent in the Kharif varieties than in the Rabi.

The Grain Smut is the commonest form found throughout the Presidency on both Kharif and Rabi crops. The Loose Smut is mainly found in the Sholapur District on the Rabi varieties of *Maldandi* and *Dagadi* though occasionally scattered in other parts. The Long Smut is almost confined to Sind but occurs sparingly in the Kathiawar States too. The Whole-head Smut is found sporadically everywhere.

Damage.

To arrive at an exact estimation of the loss caused by these smuts is rather difficult owing to fluctuation in the virulence and frequency of attack. In some years the damage done is considerable, while in others it is much less. There may be considerable variation in the amount of damage in the different fields of the same locality. Thus the attack may vary from 2 to 3 per cent. in places where it is mild to 40 to 50 per cent. in places where it is severe. Enquiries addressed to the members of the district staff of the Bombay Agricultural Department show that in the Broach District the damage varies from 10 to 20 per cent., in Surat from 4 to 10 per cent., in Khandesh from 3 to 7 per cent., in Dharwar from 5 to 15 per cent., and in Belgaum from 3 to 15 per cent. From the experiments made on the Dharwar and Gadag Farms,[3] the loss has been estimated from 20 to 30 per cent. of the yield

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[1] The monsoon crop, sown in June-July and harvested in October-November.

[2] The winter crop, sown in September-October and harvested in February-March.

[3] *Annual Report on the experimental work of the Dharwar Agricultural Station* for the year **1910-11, p. 48, Department of Agriculture, Bombay.**

per acre. On the Surat Farm where experiments have been conducted since the beginning of the Farm to demonstrate the loss caused by the smut in crops grown from untreated bazaar seed it averages up to 15 per cent. From the estimates made by the writer in the districts in a large number of fields by counting the affected heads in small areas the loss has been found to vary from 6 to 40 per cent. These figures show that the loss caused by the smuts is very great indeed.

Economic Importance.

The total acreage of the crop in the Presidency including Sind is 8,102,146 acres[1]. Even taking 10 per cent. as the average loss the total money value of the loss amounts to Rs. 2,02,55,365 (£1,350,357). By far the greater part of this damage is due to the Grain Smut. The Loose Smut and Long Smut occur only in comparatively restricted areas, and, though they cause heavy losses in the localities in which they occur, they are comparatively insignificant when the whole of the Bombay Presidency is considered. The damage from the Whole-head Smut which occurs sporadically everywhere is very little.

Effect of attack on the host.

As a rule it is not possible to detect the presence of the fungus attack in a plant until the appearance of the inflorescence. Till then the infected plant looks exactly like the healthy one in point of vigour and size. In the case of Whole-head Smut, however, the affected plant sometimes can be recognized a little before the smut mass becomes obvious. At flowering time the healthy plant shows a distinct swelling at the top due to the enclosed inflorescence, especially in those varieties which produce big ears, while in the affected plants the swelling is less marked and by a little observation such plants can be easily detected. Mr. P. C. Patil, Acting Deputy Director of Agriculture, Northern Division, informs me that he has seen cultivators' children who could pick out the affected plants before smut comes out and who eat the immature smut sori, which taste quite sweet. Potter[2] also alludes to the edibility of the smut sorus of Sorghum when young. In the case of the Loose Smut again the affected plants occasionally show definite characters by which they may be distinguished before the heads come out. The smut-affected plants, as compared with the normal ones, are rather stunted and their stalks thinner, and in some cases

[1] *Season and Crop Report of the Bombay Presidency*, 1915-16, statement III.
[2] Potter A. A. *Phytopathology*, II, 1912, p. 98.

PLATE I

Grain Smut of Jowar (*Sphacelotheca Sorghi*): *1*, smutted ear, × ½; *2*, a sorus magnified; *3*, columella left after the spores have fallen; *4*, sorus not involving stamens; *5*, sorus with stamens involved; *6*, spore germinating with promycelium and sporidia, × 450; *7*, spore germinating with branched germ-tube, × 450; *8*, promycelium with hyphæ in place of sporidia, × 450; *9*, promycelia, some constricted at first septum preparatory to being cast off, × 450; *10*, cast promycelia, × 450; *11*, promycelium with budding chains of sporidia, × 450.

PLATE II

Loose Smut of Jowar (*Sphacelotheca cruenta*): *1*, smutted ear, × ½; *2*, sorus involving stamens magnified; *3*, columella left after the spores have fallen; *4*, spores and their germination, × 450.

there is a tendency to tiller freely, and the affected heads begin to come out long before those of healthy plants (in one experiment as long as two months before the normal ones). There is no such difference observed in the other two smuts.

When the smut masses appear, it is found that the character of each kind of smut differs considerably from those of the others, so that distinction between them without microscopic examination is quite easy. In order to understand the changes in the inflorescence it is necessary in the first place to have a clear idea of the normal inflorescence. The *jowar* inflorescence is composed of paniculate racemes of heteromorphous spikelets so arranged on a central axis as to form a compact or loose head. The ultimate divisions end in branchlets which bear spikelets of which the lower one is sessile and hermaphrodite and the upper two (sometimes only one) are pedicelled and neuter, occasionally male. In the sessile spikelet there are four glumes, of which the fourth is bifid containing an awn in the middle. Within these there are two lodicules, three stamens with capillary filaments and versatile anthers, and in the centre an ovary crowned by two feathery stigmas. The pedicelled spikelets are usually as long as but narrower than the sessile ones. There are also four glumes, though sometimes only the outer two are present.

The diseased ear as a whole does not generally differ from the normal in size and shape and the central axis and its branches are quite free from the attack in the Grain (Plate I) and Long (Plate III, fig. 2) Smuts. In the Loose Smut (Plate II), however, it occasionally assumes a less compact form as compared with the healthy one, and frequently pustules are found on the axis and its branches.

When the main head is attacked, the heads arising laterally in the leaf axils and also the tillers growing from the base of the plant are invariably attacked. Occasionally the main head escapes and only the lateral heads show the disease. This is more common in the case of the Loose Smut. The new shoots springing from the affected plant after it is cut also show the disease.

In the Long Smut only a few sessile spikelets in the head are affected, the pedicelled ones usually escaping. In the Grain Smut both the sessile and pedicelled ones are involved; occasionally some of the latter are free, but the number of diseased spikelets in the heads varies very much. In some only a few are diseased, while in others more than half of them are involved. But in the majority of cases all of them are diseased. In the Loose Smut all the spikelets, both the sessile and pedicelled, are affected, though rarely some escape. Sometimes in this smut peculiar outgrowths (proliferations) of the inflorescence are

observed. The growth may start from the centre of the affected spikelet or as a branch at the base of the main inflorescence. In the former case the growth takes the form of a complete plant formed of a tiny stalk with leaves, nodes, and a rudimentary inflorescence which is also smutted. In the latter case the outer glumes of the spikelet is enlarged into a flag leaf containing in miniature an entire sound inflorescence.

Coming to the glumes, it is seen that their colour is unchanged in the Long and Grain Smuts though sometimes in the latter it is changed to purple. This purple colour, when present, is so very marked that the affected heads can be easily distinguished even in their early stage. In the Loose Smut the colour is changed to a deep green or to a dark purple.

With regard to the size of the glumes they remain unaltered in the Grain and Long Smuts. But in the Loose Smut they undergo a considerable amount of modification. They are usually enlarged, elongated, nearly glabrous, and the nerves on them are very prominent. In size they are from 10 to 20 mm. in length and 5 to 8 mm. in breadth as compared with the 5 to 7 mm. length and 4 to 6 mm. breadth of the normal glumes. The maximum length observed in the first glume was 35 mm. and breadth 10 mm. The awn of the fourth glume in all cases is either suppressed, or, when present, is usually shortened. The lodicules are either unaltered or suppressed.

The pistils and stamens are usually infected before they are very much differentiated in the flower. If the attack is very early, they are not distinguishable as separate organs but form by fusion one solid conical body. In a good many cases, however, the conical body can be seen to be formed out of three stamens and a pistil by the presence of three small points around the central one at the tip, the middle one indicating the pistil, and the three surrounding the stamens. Occasionally the pistil and the filaments are blended together, the anthers remaining quite free. At times the stamens are completely free, the pistil alone being involved. This mode of attack when only the pistil is involved, seems to be rather constant in the Grain Smut in certain Rabi varieties, and the escape or otherwise of the stamens appears to determine the form of the affected body. When the stamens are included in the attack a conical body is formed, when they escape an oblong body with a blunt tip with the stamens surrounding it is the result. In the Loose Smut it is often found that the fusion of stamens and pistils is not quite complete. Each stamen has its own infected body which joins at the base the central main one.

The stigmas usually escape infection and they can be seen in the ripened body at its tip in all the smuts. Eventually they dry up and vanish.

Fig. 1. Whole-head Smut of Jowar (*Sorosporium Reilianum*): smutted ears, × ⅓; spores and their germination, × 300.

Fig. 2. Long Smut of Jowar (*Tolyposporium filiferum.*)

In the early stage the affected body is covered by the glumes and therefore is not visible. It comes out as it grows and on maturity is distinctly seen. It shows great variations with regard to size and shape in the different smuts. In the Grain Smut it is generally, compared with the normal seed, an elongated, sometimes slightly bent when long, thickened, club-shaped body, tapering to a point at the free end. Sometimes it assumes an oblong shape with a blunt end. As already mentioned this is due to the escape of stamens. In the Long Smut it is cylindrical in shape, usually curved, and abruptly coming to a point at the free end. It is from 3 to 12 mm. in length and 2 to 4 mm. in breadth in the Grain Smut; from 3 to 18 mm. in length and 2 to 4 mm. in breadth in the Loose Smut; and in the Long Smut from 6 to 25 mm. in length and from 4 to 6 mm. in breadth.

In the case of the Whole-head Smut (Plate III, fig. 1) the changes produced are quite different from those above described for the other kinds. The whole of the inflorescence, including the rachis, is converted into a fibrous spore mass protected by a whitish membrane which is very transient. In the beginning the sorus is enclosed by the leaf-sheath through which it comes out, either partially or completely exposing a dark spore mass and the ray-like remains of the fibro-vascular threads of the host tissue. Sometimes the affected plants produce a smut-free inflorescence which however is sterile. In such cases the glumes of the spikelets are elongated and decolorized, and hence the head as a whole looks pale and the sorus appears either just below the head itself or lower down on the main stem. Frequently pustules are found on the leaves surrounding the sorus.

The membrane of the sorus in all cases is whitish in colour. In the Grain Smut it is of two sorts. In one case it has a brownish tinge in the early stage, which on maturity turns to dull grey; while in the other it is shining grey and on maturity turns to pale grey. In the Long Smut it is shining greyish-white. In the Whole-head Smut it is bright porcelain-white when fresh and turns to dull white on drying.

On ripening the membrane usually ruptures and exposes the spores. In the Grain Smut this process is very variable. In some cases the membrane gets broken just after maturity, and in some it remains intact for a time. In others again it is so very tough that it never ruptures unless it sustains some mechanical injury. In the Long Smut it opens, after maturity, usually at the tip, occasionally by cracks in the middle. In the Loose and the Whole-head Smuts it is very transient and ruptures even before the head emerges from the sheath.

Soon after the rupture of the membrane the spores are exposed and scattered by the wind. Afterwards there remains in the sorus nothing

but a slender hard mass of host tissue known as the columella, which differs according to the kind of smut. In the Grain Smut it forms a stiff, slender, rather straight column, narrowing somewhat irregularly from the base towards the apex, and terminating before reaching the end of the sorus. In the Loose Smut it differs from the above in being longer and curved. In the Long Smut it consists of a bundle of 8 to 10, sometimes more, dark brown filaments, usually joined at the base. In the Whole-head Smut it is composed of innumerable solid filaments inextricably tangled into a net-work.

Spores.

In the Grain Smut the spores are powdery and appear dark brown in mass. Singly they are brown, smooth-walled, and 4 to 6μ in diameter. In the Loose Smut they appear quite black in mass, while individually they are dark brown, with minutely pitted walls, very variable in size, usually from 4 to 8μ. In the Long Smut they are granular in mass, being formed in dark coloured balls consisting of numerous spores firmly held together. Singly they are brown in colour, of irregular shape, mostly globular or oblong, thick walled, tubercled, and from 8 to 14μ in size. The spores in the centre of the spore-ball are paler brown than those at the surface and do not clearly show the tubercles on their walls. In the Whole-head Smut they are deep brown in colour, globular or somewhat angular, minutely tubercled, and from 8 to 16μ in size. Sterile cells of subspherical shape, often in groups, are sometime seen scattered in the spore mass.

Germination.

The spores of Grain and Loose Smuts germinate very easily in water. They begin to sprout within 6 hours of sowing and at 12 hours germination is very vigorous. At first a small, hyaline, straight or often bent tube (rarely two) appears, which gradually lengthens and forms what is known as the promycelium. From 2 to 4 transverse septa are soon formed, dividing it into 3 to 5 segments. In the early stages the septa are not clearly seen owing to the granular appearance of the protoplasm, but they are easily made out when stained with cotton blue. The so-called buckle or knee joints are very common. They are formed by a branch growing out from the end of one of the segments, near the septum, and then curving round to effect a communication with the next segment. A knob-like joint is thus formed, and the promycelium is usually bent at

PLATE IV

Long Smut of Jowar (*Tolyposporium filiferum*): *1*, ruptured sori; *2*, a spore ball; *3*, part of same in section, × 450; *4*, germination, × 450.

such joints. Sporidial formation is scarce. When formed the sporidia appear at the tip of the promycelium or laterally at the septa, either just above or below them. They are spindle-shaped and are borne directly on an elongated slender sterigma which soon breaks, so that the sporidia are mostly found free from the main body. They do not seem to bud off secondary sporidia to any great extent. More usually, instead of sporidia, long slender hyphæ, which are frequently of considerable length, grow either from the apex of the promycelium or from the knee-joints or segments. Sometimes the promycelium is not distinct but a branching germ-tube arises in its place. Occasionally the promycelium is cast off wholly from the spore. The mode of germination in the Grain Smut and the Loose Smut is identical except that the promycelium in the Loose Smut is slightly thicker. In nutrient solutions (dung solution or tomato broth) the germination is more vigorous; stouter and thicker promycelia are formed and the sporidia develop very abundantly. The latter are bigger than those in water culture and bud very freely. The formation of knee-joints and of branching germ-tubes or the production of hyphæ instead of sporidia on the promycelium, are less often observed.

The spores of the Long Smut germinate in water, dung solution, tomato broth, or glucose peptone culture solution[1]. But Busse succeeded in germinating them only in the last solution. Germination was observed after 24 hours, a good many spores of each cluster sprouting as a rule. The promycelium is generally 3-celled, longer than either of the above two smuts, and bears sporidia at the tip and laterally from near the septa, often in clusters. These either produce secondary sporidia by budding or grow into long germ-tubes. The promycelium is sometimes much branched, or often instead of a true promycelium the spore germinates by a hypha, the protoplasm of which collects in the upper growing part while the lower becomes empty and cut off by successively formed septa.

The spores of the Whole-head Smut are difficult to germinate. Attempts to germinate them in water or nutrient solutions were not successful. They were tried in different seasons and at various times of the year. The variations of temperature such as 16°, 20°, 30° and 40°C. did not have any effect, although Potter in America has succeeded in getting some germination at 30°C. It is known that freezing sometimes promotes the germination of spores, and, in order to test this, some

[1] This solution is composed of—

Water	400 c.c.
Glucose	8 per cent.
Peptone	1·5 per cent.
Magnesium sulphate	0·1 per cent.

and a trace of sodium phosphate.

were kept in a closed dry test tube in ice for 24 hours. This seemed to have some effect on them as a scanty germination was then obtained on sowing in water.[1] A short, thick promycelium, thicker than those of the three previous smuts, is formed, having 2 to 3 septa. No further progress was seen except a few sporidia which were borne terminally or laterally. Repeated trials did not show any further growth.

Infection.

According to previous workers (*e.g.* Brefeld[2], Clinton[3] and Potter[4]), infection in the Grain and Loose Smuts takes place at the seedling stage through the seed-borne spores. Our out-door experiments both in the field and in pots prove the same thing.

Pot experiments, 1912. Plants were raised in wooden tubs in each of which 13 seeds were put. Before sowing the seed was mixed with spores and was divided into two parts ; one part was sown untreated and the other was dipped in 2 per cent. copper sulphate solution for 10 minutes.

Serial No. of pot	No. of seed mixed with spores	Plants grown	Plants smutted
1	13 seeds were dusted with the spores of Loose Smut	13	13
2	13 seeds mixed with Loose Smut spores but treated with 2 per cent. $CuSO_4$ for 10 minutes	13	nil
3	13 seeds mixed with the spores of Grain Smut	13	11
4	Ditto Ditto	13	9
5	13 seeds with Grain Smut spores but treated with 2 per cent. $CuSO_4$ for 10 minutes	13	nil

Field experiments, 1914. These were carried out at two places, on the College Farm and the Ganeshkhind Botanical Gardens, in small plots of half a *guntha*[5] in area. All the four smuts were tried. The

[1] The room temperature of the laboratory was 30°C.
[2] Brefeld. "Untersuchungen," XV, 1912, p. 31.
[3] Clinton G. P. "Broom corn smut," *Illinois Agri. Exp. Sta. Bull.* 47, 1897, p. 391.
[4] Potter, A. A. *Phytopathology*, V, 1915, p. 151.
[5] A *guntha* is equal to $\frac{1}{40}$th of an acre.

same process of mixing the spores and then treating half of it with $CuSO_4$ was followed

Serial No. of plot	Treatment	Percentage of attack	Kind of Smut
1	Seed mixed with spores before sowing	20 per cent. in the College Farm and 17 per cent. in Ganeshkhind Botanical Gardens	Grain Smut
2	Seed mixed with spores and then treated with 2 per cent. $CuSO_4$ for 10 minutes	Nil in both the places	
3	Seed mixed with spores before sowing	60 per cent. in the College Farm, 40 per cent. in Ganeshkhind Botanical Gardens	Loose Smut
4	The same seed treated with 2 per cent. $CuSO_4$ for 10 minutes	Nil in both the places	
5	Seed mixed with spores	Ditto . .	Long Smut
6	The same seed treated with 2 per cent. $CuSO_4$ for 10 minutes	Ditto . .	
7	The seed mixed with spores	Ditto . .	Whole-head Smut
8	The same seed treated with 2 per cent. $CuSO_4$ for 10 minutes	Ditto . .	

These experiments show that infection occurs with seed-borne spores in the case of *Grain* and *Loose* Smuts and not in *Long* and *Whole-head* Smuts, and that in the first two copper sulphate seed treatment is effective in checking the disease.

Soil infection in the Grain and Loose Smuts does not seem to take place. It has been found that though spores of both retain their vitality for at least 2 years if kept dry (in certain cases they are said to have been germinated even after 6½ years), still under the ordinary alternating wet and dry conditions of the soil they do not seem to survive more than a few months. They probably germinate on the first fall of rain and perish when drought sets in unless they encounter the host plant. On the Dharwar Farm artificial infection of the soil of two plots, each

of 2 *gunthas* in area, with the spores of the Grain Smut, two months before sowing, did not produce infection in a single plant. Nor did infection occur in the case of pot experiments conducted in Poona. The spores of both the Grain and Loose Smuts were used and they were mixed in the soil 3 months previous to sowing. In these experiments seed before sowing was treated with 2 per cent. copper sulphate solution.

With regard to the Whole-head Smut, however, soil infection seems to be the chief mode of attack. This has been practically established by Potter[1] in America and our observations here also confirm it. Seed treatment does not check it ; furthermore the spores germinate irregularly (unlike the Grain and Loose Smuts), many failing to sprout when sown in water, so that they could remain in the soil through several wet and dry periods without losing their vitality and thus infect the seedlings when the next crop is sown. But the number that germinates each time appears to be very small as is evident from the way the disease appears in a few plants scattered through the fields.

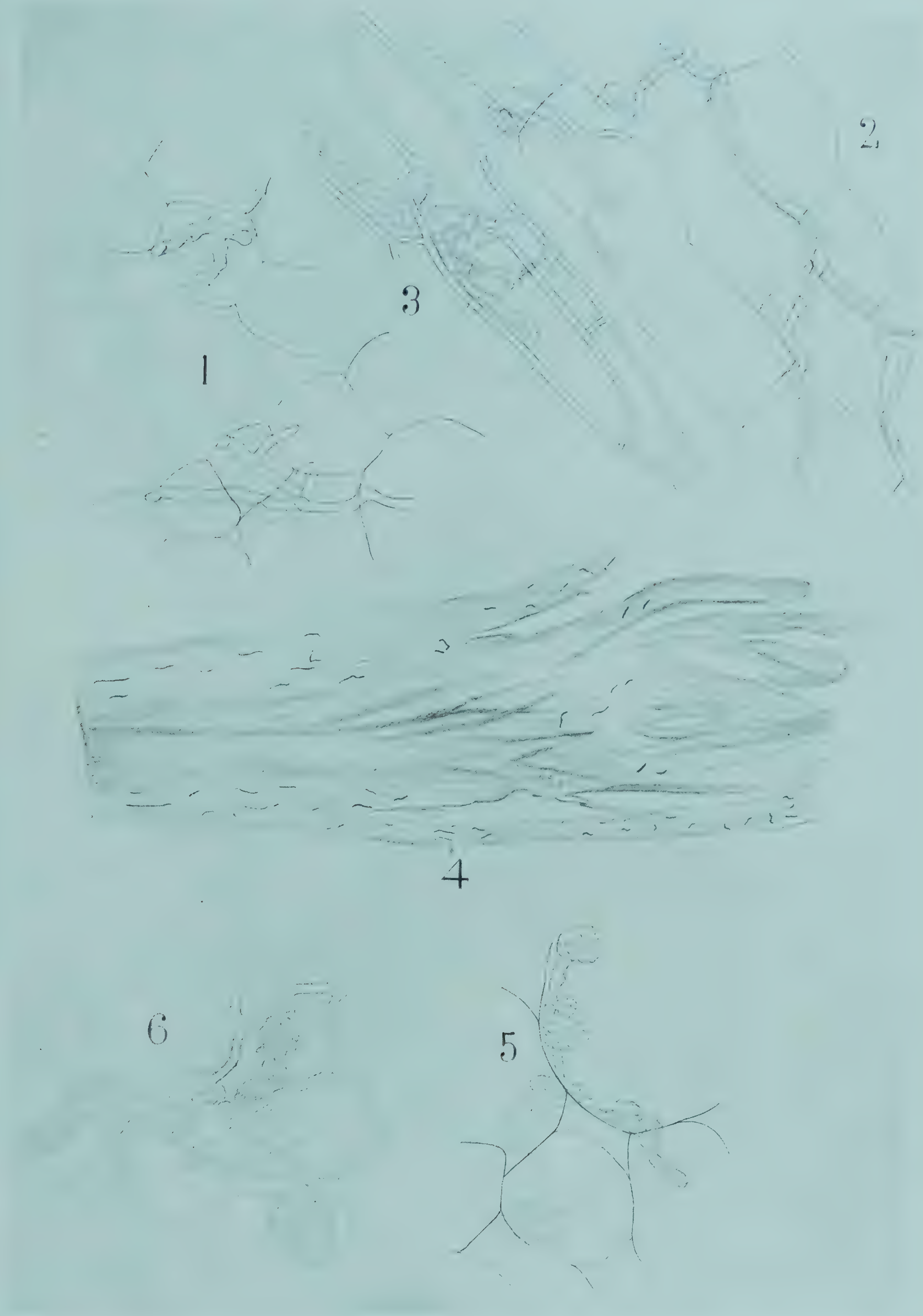
In the Long Smut, infection from spores adhering to the grain coats and sown with the seed does not seem to take place as we have already seen, and experience from Sind, where this smut occurs regularly, has shown that seed treatment is not effective in checking the disease. Its further life-history is not known. Whether infection is through the flower or through the spores in the soil from the previous crop is still to be worked out.

No further work was done with regard to the Long and Whole-head Smuts. The work described below refers only to the Grain and Loose Smuts.

Infection appears to take place only when the germ tube of the spore or the sporidium comes in contact with the young cells of the shoot. Entry is effected by the hyphæ growing through the epidermal cells of the primary shoot below the soil level, and the susceptibility is limited to the period of about 2 to 6 days between the moment of germination and the emergence of the first green leaf from its colourless sheath. This period varies somewhat according to temperature and moisture.

In a germinating *jowar* seed we find two members, one the descending axis which comes out first and forms the primary root, the other the ascending axis which forms the shoot. Soon after germination, growth at the base of the bud increases, and consequently a short internode is formed, connecting the seed at one end and the plumulary bud at the other. This internode is known as the mesocotyl, and the sheath enclosing the stem bud is known as the coleoptile. The latter

[1] Potter, A. A. "Head Smut of *Sorghum* and Maize." *Journal, Agri. Res.*, II, 1914, p. 367.



1, infection hyphæ of ***Sphacelotheca Sorghi*** entering through epidermal cells; **2,** hyphæ of same in ground tissue after infection; *3,* hyphæ of same in bundle parenchyma; *4,* diagramatic sketch of longitudinal section of growing point of *jowar* seedling, showing the position of hyphæ which are mostly in the ground tissue but are also found in the outer sheath and at the base of the first leaf; a few are just below the growing point; *5,* hyphæ of *Sphacelotheca cruenta* in pith cells of an internode from the middle of a full-grown plant; *6,* hyphæ of same at a node of the same plant.

is soon pierced by the growing leaves of the stem bud, after which the growth of the mesocotyl ceases.

Temperature. At low temperatures *jowar* will germinate very slowly. Its rate of germination increases as the temperature rises and is at its optimum at 36° to 40°C. Thus at 16°C. it takes from 4 to 6 days for the first leaf to appear. At 20° to 23°C. it requires 3 to 4 days; at 30°C. 2 to 3 days and at 37°C. 1½ to 2 days. The spores of both the smuts germinate quite easily at moderate temperatures. The optimum temperature is 20° to 23°C., below or above which the rate of germination falls. At 16°C. about 70 per cent. of the spores of both Grain and Loose Smuts germinate, at 20° to 23°C, about 90 per cent., at 30°C. about 60 per cent., and at 37°C. only 1 to 2 per cent. If the temperature of germination be compared for the spores and the *jowar* seeds, it is found that infection is most likely to succeed at moderate temperatures, say, between 16°C. and 30°C., at which the spores germinate very freely, while the growth of the *jowar* seedling is retarded so that the susceptible stage is prolonged. The temperature, therefore, seems to be the chief controlling factor in the distribution of these smuts. We have already seen Kharif varieties are more susceptible to smut than the Rabi and even in the Kharif the tracts having higher rainfall have more smut than those having less rainfall. As we pass eastwards away from the Western Ghats the rainfall decreases while the temperature gradually rises. The Kharif *jowar* is sown in June-July, when the weather is usually cold and wet and the average temperature is between 21°C. and 27°C., which, as we have already seen, is most favourable for the spores to germinate, while *jowar* germinates rather slowly and consequently the susceptible stage is lengthened and infection is more certain. In the case of Rabi *jowar*, which is usually sown in September-October, the weather is dry and warm and naturally the temperature is higher than in June-July and therefore more favourable for the rapid growth of the *jowar* seedling whose susceptible stage is passed over soon. This is the probable explanation why smut is worse in the Kharif than in the Rabi crop[1].

Moisture. Successful infection is also influenced by soil moisture at the time of sowing. The seed bed may be just damp enough to allow the spores to germinate while insufficient for *jowar*. In this case the germ-tubes perish before infection can take place. When the moisture is more than sufficient for both the fungus and the host the germination

[1] The general rarity of these smuts in the Indo-Gangetic plain, *viz.*, Sind, the Punjab, United Provinces, and Bihar, also seems to depend upon the temperature factor. In all these provinces the average temperature at the sowing time is between 32°C. and 38°C. which is too high for the spores to germinate and therefore infection is very little. Laboratory and field experiments are in hand to confirm this.

of seed is so rapid that the young seedling may outstrip the germinating spores and thus be too far advanced for successful infection to take place. Thus it was found that 2·5 and 5 per cent. water added to air-dried soil was not sufficient for the seed to germinate but was enough for the spores to sprout; while with 7·5, 10, 15 and 20 per cent. *jowar* seed germinated easily, the rapidity of growth of seedlings being dependent on the quantity of moisture, the greater the moisture the more rapid the growth. The photograph (Plate VI) shows well the relative rapidity of germination according to the quantity of moisture after three days. It will be noted that plants in the 20 per cent. moisture pot are the most vigorous and the tallest. Those in 15 per cent. are a little shorter than the first. Those in 10 per cent. are still shorter, and those in the 7·5 per cent. are the shortest.

Laboratory experiments. These were done to determine exactly the part of the seedling at which infection takes place. Seedlings were raised in sterilized Petri dishes, and the seeds before sowing were washed in ½ per cent. formalin for two minutes. Infection in both the Grain and Loose Smuts was most common in those seedlings whose seeds were dusted with spores before sowing. Attempts made by placing germinated or ungerminated spores on the mesocotyl or on the coleoptile were not successful, but in a few cases infection took place in plants whose coleoptile was removed and spores placed on the young leaves. In the infected plants from these seeds which were dusted with spores hyphæ were found most abundantly near the upper part of the mesocotyl at the node from which the coleoptile arises and not towards the base. This shows that infection takes place in the very early stage when the mesocotyl is just being formed.

After infection of the primary shoot the hyphæ rapidly grow into long, irregularly branched, thin-walled, hyaline threads, that ramify freely into the tissues of the plant. They run between and through the cells and some grow straight towards the growing point. They are mostly found in the ground tissue surrounding the central vascular tissue and also in the cells round the bundles when they are separated. They are also seen in the base of the leaf-sheath and in the lower parts of the first leaves. Septa are not clearly seen in the young growing hyphæ but can be made out in older threads. Frequently the cell walls are swollen, and consequently the hyphæ have a lobulated appearance. In full-grown plants the hyphæ become more limited to the intercellular spaces and send in haustoria, which are seldom spherical but most frequently like a bunch of grapes. In the internodes they are usually few and scattered, being most abundantly found at the nodes. Though the mycelium seems to penetrate the entire plant,

Germination of *jowar* in air-dried soil in four pots, to which had been added 20, 15, 10, and 7·5 per cent. (by weight) of water respectively.

it does not seem to be continuously connected. At the nodes it remains dormant, and when fresh shoots are formed it enters into them and causes the attack of lateral shoots as already mentioned.

Once the growing point of the host is reached the mycelium follows the upward growth of the plant by its continuous growth, producing no apparent effect on its host until the formation of the ear. Then the hyphæ accumulate in the young ovaries below the epidermis, forming a solid mass of considerable depth, and by their pressure the epidermis on the outside and the tissue cells inside are gradually crushed and disorganized. The outer part of the fungus tissue forms the membrane, while the spores are formed in the rest of the fungal mass progressively from without inward, the final result being the sorus with its membrane outside, a mass of spores within, and a part of the vascular tissue of the host left as the columella in the centre.

Even after successful infection has been accomplished the fungus may not be able to keep pace with the fast growing shoot which may escape and produce a sound head. In such cases the hyphæ remain dormant at the nodes and may infect the side shoots when they appear.

While it is mainly through the wind that the spores are carried to the sound grains either in the standing crop or in the threshing yard, it is highly probable that small black beetles are also concerned in it, for they are invariably seen flying about on the smutted heads.

Some smuts are known to be injurious to the health of men or animals fed on smutted grain. Thus maize smut is said to produce the same bad effects as ergot. The green fodder of *Glyceria spectabilis* affected with *Ustilago longissima* is known to be injurious to cattle[1]. Bunt in wheat is said to be harmful to pregnant animals and is known to affect seriously the egg-laying capacity of fowls in Australia[2]. But so far as experience goes in the Bombay Presidency, no instances of these with regard to the *jowar* smuts have been recorded, nor have any complaints been heard recently. Cultivators are in the habit of feeding the smutted plants to cattle without noticing any ill effects on them. The young sorus of the Whole-head Smut is eaten by children with impunity. Nor has the smutted grain been known to cause any derangement in the health of persons who use it for food.

Nomenclature.

There is still a considerable difference of opinion among mycologists with regard to the naming of some of these *jowar* smuts. No two

[1] Eriksson. "Giftiges sussgras von Ustilago longissima befallen". *Zeitschrift fur Pflanzenkrankheiten*, 1900, p. 15.

[2] McAlpine. *The Smuts of Australia*, p. 81.

writers seem to agree, and even in recent literature these smuts have been placed under different genera. There are in all six kinds of smuts recorded on *jowar*. On referring to the descriptions and illustrations of these in recent literature, and also comparing with the specimens in the Pusa herbarium where all the Indian material and some foreign exsiccata are found, these smuts have been determined as under.

(1) Grain Smut, *Sphacelotheca Sorghi* (Link) Clinton. Vernacular names: Marathi—Dane kani, Karde kani; Kanarese—Kalugadige, Godigadige.

This was first recorded on *jowar* in 1825 by Link who named it *Sporisorium Sorghi*[1]. In 1847 Tulasne called it *Tilletia Sorghivulgaris*[2], and in 1873 Passerini named it *Ustilago Sorghi*[3]. In 1874 Kühn, having studied its germination, called it *Ustilago Tulasnei*[4]. Clinton in 1897 from a study of the mode of its spore formation transferred it to the genus Cintractia[5], and finally the same author put it in Sphacelotheca in 1902[6]. The following is the technical description.

Sori formed of pistils and stamens blended together, occasionally the latter escaping, forming a conical body, slightly bent when long, from 3 to 12 mm. in length and 2 to 4 mm. in breadth, at first protected by a greyish membrane which on rupture liberates spores, leaving a distinct columella in the centre formed of host tissue. Spores in mass dark brown, singly brown, smooth-walled, and 4 to 6μ in diameter. The fungus membrane is from 30 to 80μ in thickness and is composed of hyaline, subglobose or oblong cells, and in the early stage bounded by one layer of epidermal cells of the host.

On *Andropogon Sorghum* throughout the Bombay Presidency.

(2) Loose Smut, *Sphacelotheca cruenta* (Kühn) Pot. Vernacular: Marathi—Kajali.

This smut was first described by Kühn in 1872[7] as *Ustilago cruenta*. The chief distinguishing characters which he noticed were the red colouration and the formation of pustules on the panicle branches. As these characters are not constant it has been frequently confused with *S. Sorghi*. **Brefeld**[8], who also studied it, at first did not consider it as a distinct species although afterwards he separated it from *S. Sorghi*. Clinton does not mention it. Potter[9] called attention to it in 1912.

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[1],[2],[3],[4], Quoted by Clinton." Broom corn smut ". *Illi. Agri. Exp. Sta. Bull.* 47, p. 403.
[5] *Ibid*, page 388.
[6] " North American Ustilagineæ." *Proc. Boston Soc. Nat, History*, XXXI, p. 38.
[7] Quoted by Potter, A. A. *Phytopathology*, V, 1915, p. 149.
[8] Quoted by Potter, A. A. *loc. cit.*, p. 150.
[9] Potter, A. A. *Phytopathology*, II, 1912, p. 98, (Abste).

It was Busse[1] in 1904 who first noted the fragile character of the membrane of the sorus—the chief and constant character—and recently in 1915[2] Potter described it again pointing out clearly the differences between it and *S. Sorghi.* Our specimen agrees in every respect with his description.

Sori in the ovaries, sometimes on the rachis and its branches, forming an oblong, club-shaped body, tapering to a point, from 3 to 18 mm. in length. Membrane very transient, spores dark in mass, singly darker brown than the last, with minutely pitted walls, 4 to 8μ in size. Columella long and curved.

The glumes of the spikelets are enlarged. The membrane is from 20 to 40μ in thickness and consists of round cells which are sometimes seen mixed with spores. This is also surrounded by a layer of host epidermal cells.

On *Andropogon Sorghum* (mainly on the Rabi varieties) in the Sholapur District.

(3) Long Smut, *Tolyposporium filiferum* Busse.

Busse[3] described this fungus for the first time from East Africa in 1905. The Indian specimen agrees with his description.

Sori in the ovaries, cylindrical in shape, often bent, from 6 to 25 mm. in length, protected by a greyish membrane which on rupture exposes spore mass from 40 to 120μ, irregular in shape, granular in character, consisting of spore-balls which are quite firm. Spores are brown, globular or oblong, with tubercled walls at the free side, and from 8 to 14μ in size. Columella consisting of 8 to 10 fine threads which are joined at the base. The membrane is composed of fungus cells and is from 40 to 80μ in thickness.

On *Andropogon Sorghum* in Sind.

(4) Whole-head Smut, *Sorosporium Reilianum* (Kühn) McAlpine. Vernacular : Marathi—Ziprya ; Kanarese—Budigadige, Hittugadige, Chontigadige.

This smut was first described by Kühn[4] in 1875. Saccardo[5], 1878, de Toni,[6] 1888, and Norton[7], 1896, noticed the aggregations of spores suggestive of Sorosporium. Clinton[8] in 1900 mentioned it under Cintractia and in 1902[9] under Sphacelotheca, McAlpine[10] in 1910 placed

[1] Busse, W. " Krankheiten der Sorghumhirse ". *Arb. Biol. Anst.*, IV, 1904, p. 319-426.

[2] Potter, A. A. *Phytopathology* , V, p. 149.

[3] Busse, W. *loc. cit.*, p. 383-86.

[4, 5, 6, 7] Quoted by Potter, A. A. *Jour. Agri. Res.*, II, p. 340.

[8] Clinton G. P. " The smuts of Illinois Agri. plants. " *Illi. Agri. Exp. Station Bull.* 57, p. 346.

[9] Clinton, G. P. " North American Ustilagineæ." *Proc. Boston Soc. Nat. Hist.*, XXXI, p. 393.

[10] McAlpine. *The Smuts of Australia*, p. 181.

it, owing its formation of spore balls in the early stage, in the genus Sorosporium, and Potter,[1] 1914, agrees with him. The writer also noticed, on sectioning immature sori, spores developing around fibro-vascular bundles in groups in the earliest stages. The appearance agreed with the illustrations of McAlpine and Potter.

Sori very prominent, appearing mostly in the ears, often on the stem and upper leaves, at first enclosed by the leaf-sheath, protected by a transient whitish membrane which on rupture exposes a black spore mass and the ray-like remains of the peduncles or columellas. Spores round or angular, minutely verruculose, 9 to 14μ in size. Sterile cells, often in subspherical groups, are seen scattered through the spores.

The membrane is composed of fungus tissue formed of long threads consisting of oblong cells and is from 60 to 150μ in thickness.

On *Andropogon Sorghum* found sporadically throughout the Bombay Presidency. This was once found on maize at Dohad in 1910.

Preventive Measures.

The cultivators, although they are quite ignorant of any efficient remedy to prevent smut, still follow certain practices, which, though crude and ineffectual, are in the right direction in that they secure the destruction of affected plants and seeds. Thus in the Southern Maratha Country the cultivators are in the habit of picking out smutted plants from the standing crop and feeding them to cattle. This is not done with any intention of checking the disease but simply because they know these plants will not produce any grain, and in doing this they follow a sound principle in disease control, *viz.*, the destruction of affected plants. In this way a good many plants are removed before the crop ripens. Again at the harvesting time the smutted heads are sorted out and separately threshed, though in the same yard and just near the sound heads, and the little grain got from such heads is not mixed with the general produce. Thus a large quantity of the infective material is removed, and consequently the general contamination of the seed is minimized. Again in some places of the Karnatak there is a practice which not only avoids the general distribution of such affected seed but aims at its complete destruction too. This is due to a superstition among the people that the seed got from smutted heads is the gift of the Goddess of Wealth, which is to be kept solely for the use of the family and not by any chance sold with the other produce of the farm or given away even in charity. Cultivators, therefore, take particular care to make it into bread and consume it at home.

[1] Potter, A. A. *Journ. Agri. Res*, II, p. 341.

As to the origin of this belief it may be suggested that a wise man in former times discovered the true reason for not mixing the diseased seed with the sound. The difficulty would then be to find out a rule to suit the people whereby the discovery might be brought into practical use. Had he tried to make use of it by stating that by mixing the smutted seed with the normal grain one would get more smut in the coming crop, he would not have been heard at all. He might then think of popularizing his methods of dealing with the disease by working on the superstition of the cultivator and inculcating the idea that to part with the grain from smutted heads is to incur the wrath of the Goddess of Wealth.

As already known infection of the plant takes place through the seed-borne spores at the seedling stage in the case of Grain and Loose Smuts. One way to prevent this would undoubtedly be to use seed entirely free from smut spores. But this is by no means an easy thing to do owing to the ubiquitous presence of the disease in every field except the Government Farms, where by continuous preventive efforts the smuts are completely checked. Again, even apparently clean seed is no guarantee unless its source is known, as the adhering spores are too small to be seen by the naked eye.

Another way is to treat the seed with some fungicide so as to kill the adhering spores without in any way injuring the grain. For this purpose various kinds of treatments and chemicals are used in Europe and America, such as hot water, formalin, copper sulphate, corrosive sublimate, potassium sulphide and so on. Among these the first three remedies are those that are usually recommended. In the hot water treatment the grain is first heated in warm water for a few minutes and then immersed in water at about 135°F. for 10 to 15 minutes. Below 130°F. does not kill the spores and above 140°F. is dangerous to the grain. This treatment, though quite effective and highly advocated in America, is troublesome and complicated as it requires the seed to be treated at a particular constant temperature. A little neglect in the operation may seriously injure the germinating capacity of the grain. Besides when large quantities of grain are to be treated it becomes a lengthy and tiresome process. It is therefore not suited to the Indian cultivator who is too ignorant to understand the technicalities of this treatment owing to his illiteracy. What he requires is an easy, quick, and cheap method, and the material must be got easily. The formalin treatment too, which is being adopted on a large scale in foreign countries, is not suited to the Indian conditions as formalin is difficult to get except in very big cities.

The copper sulphate remedy is the only one which fulfils all the requirements. There is one possible objection to this treatment, namely, that it may injure the germinating capacity of seeds treated. Thus it is well known that this method is somewhat injurious to cereals such as wheat, barley, and oats. Recently Mr. Ajrekar, Assistant Professor of Mycology, Agricultural College, Poona, also experienced a similar injurious action of $CuSO_4$ treatment in the germination of sugarcane sets while experimenting with the sugarcane smut.[1] In order to determine how far it is true in the case of *jowar* the following experiment was made. Seed was treated in different strengths ranging from ½ per cent. to 5 per cent. for 10 minutes, and after drying completely its germinating capacity was tested in the seed-testing laboratory of the Agricultural College, Poona. The following are the average results of 5 trials.

No.	Strength of $CuSO_4$ solution	Time for which seed was dipped	Percentage of germination
1	Normal seed . .	....	90·5
2	Seed dipped in ½ % .	10	94·0
3	" " 1 % .	10	93·0
4	" " 2 % .	10	91·5
5	" " 3 % .	10	90·5
6	" " 4 % .	10	83·0
7	" " 5 % .	10	82·5

It is clear from the experiments that seed can be dipped in solution even up to 3 per cent. strength safely.

Next it was necessary to determine the minimum strength of $CuSO_4$ required to prevent smut. Various workers have recommended various strengths according to the kind of smut. Even in India different strengths are advocated in different provinces. In Bombay, Mollison advocated ½ per cent. for 10 to 15 minutes. McRae in Madras advocates 2 per cent. for 15 minutes. Coleman in Mysore advocates either ½ per cent. for 16 hours or 1 per cent. for 15 minutes. In the Central Provinces 2 per cent. is advocated. The following experiments were conducted to ascertain the exact strength. Seed was mixed with spores and was then divided into four lots. One lot was sown as untreated,

[1] The *Agricultural Journal of India*, vol. XI, part III, p. 294, July 1916.

and the remaining three lots were treated with different strengths for 10 minutes as seen below.

Place and kind of smut	Strength of solution	Percentage of attack
College Farm, Poona— Loose Smut, Plot No. 1	½ per cent. for 10 minutes .	nil
„ „ 2	1 per cent. „ „ .	nil
„ „ 3	2 per cent „ „ .	nil
„ „ 4	Seed untreated	60 per cent.
Ganeshkhind Botanical Gardens, Kirkee, Poona— Grain Smut, Plot No. 1	½ per cent. for 10 minutes .	nil
„ „ 2	1 per cent. „ „ .	nil
„ „ 3	2 per cent. „ „ .	nil
„ „ 4	Seed untreated	20 per cent.
Ulewadi near Sholapur— Plot No. 1	½ per cent. for 10 minutes .	nil
„ „ 2	1 per cent. „ „ .	nil
„ „ 3	2 per cent. „ „ .	nil
„ „ 4	Seed untreated . . .	10 per cent.

These experiments show that even ½ per cent. strength is quite effective in preventing smut, and there is thus a large margin of safety before any injurious effect on the seed need be feared.

The effect of treatment on the spores themselves. This was studied to see how far the treatment was effective in killing the spores. Copper sulphate solutions ranging from ½ per cent. to 5 per cent. were prepared in six Petri dishes. In each solution a little quantity of spore was put and was thoroughly shaken so as to wet all the spores and then was left for 10 minutes. Afterwards each solution was filtered and the spores collected on the filter paper were thoroughly dried. They were then placed

separately in nutrient solutions for germination. After 24 hours it was found that in all cases some of the spores were germinating. No exact account was made to determine the percentage, but it was seen even 5 per cent. strength was not sufficient to kill all the spores. The question then arises how it is that strengths from ½ to 2 per cent. are effective in checking the disease in seed treatment. A possible explanation given is that in drying the grains subsequently to steeping the precipitate left on the surface of the seeds may be toxic to the germ-tubes of the spores[1]. This explanation naturally raises the question of the reinfection of the seed after treatment, and the special precautions recommended by some to be taken after the seed is treated, such as not to use smut-infested bags or seed drills not properly cleaned, seem to be quite unnecessary. In order to investigate this question the following experiment was conducted. Three lots of seed were taken, one was treated with 2 per cent. copper sulphate solution for 10 minutes, another with ½ per cent. formalin for 10 minutes, and the third was untreated. When the first two were thoroughly dried, all the three were dusted with smut spores and sown separately.

Treatment	Percentage of Smut		
	College Farm	G. B. Gardens	Dharwar Farm
Seed treated with 2 per cent. $CuSO_4$ and then mixed with spores	nil	nil	nil
Seed treated with ½ per cent. formalin and then mixed with spores	3 per cent.	nil	nil
Untreated mixed with spores	10 per cent.	5 per cent.	3 per cent.

These experiments prove that in the case of copper sulphate treatment reinfection from fresh spores does not take place, and therefore confirm the above theory. In the case of formalin treatment reinfection does take place to some extent. Formalin leaves no deposit on drying and has all evaporated by the time the seed is sown, and consequently there remains nothing on the seed coat to prevent fresh spores from reinfecting.

[1] *Monthly Bulletin of Agricultural Intelligence and Plant Diseases. International Institute of Agriculture, Rome*, IV, no. 7, July 1913, p. 1039.

Thus the copper sulphate treatment can be recommended with confidence[1] to the cultivator against the common smuts (Grain and Loose) of Jowar as a cheap, quick, efficient, and easily practicable method. It is cheap because the material (two *tolas*[2]) sufficient for seed for one acre will not cost more than three pies. It is efficient as it gives cent per cent. results by completely checking the disease. It is quick because it does not require more than 15 minutes, and practicable as it can be practised by anybody.

All one has to do is to procure an earthen or wooden vessel which can be got in any village. Into this pot 100 *tolas* of water by weight are put (when weighing is not possible two measures by an ordinary rock oil bottle will do). The powdered copper sulphate (2 *tolas*) is put into the water and stirred well till it is dissolved. Then the seed for sowing is plunged into the solution and allowed to remain for 10 minutes, after which the liquid is strained and the seed dried ; it is then ready for sowing. All this process does not take more than 15 minutes.

This treatment for the Whole-head Smut as already observed is not effective. The only measure that can be recommended is to destroy the affected plants as soon as they appear, before the spores reach the soil. Fortunately the damage caused by this smut is so little that any further measures are for the present unnecessary.

In the case of the Long Smut no remedial measures can be suggested as its life-history is not fully known.

The copper sulphate treatment is now widely advocated by the Bombay Agricultural Department and is practised by the cultivators.

It may be of interest here to give an account of the efforts of the Department in the way of making this treatment widely known to the cultivators. The method is not new inasmuch as it was already known within and outside India. It, therefore, attracted the attention of the very first officers of the Department and was included in the cropping schemes of all the experimental farms wherever they were started. Thus we find it mentioned in the report of the Bhadgaon Farm as early as of 1885, in the first report of the Surat Farm, and in that of the Dharwar Farm. In those early days as there were no special district officers of the Department, the information used to reach the cultivators through the Revenue Officers. The first strenuous attempt in this

[1] This treatment is not quite satisfactory in the case of those varieties of *jowar* whose grain coats have any peculiarities which would interfere with the solution wetting them completely. Thus in the case of a few fodder varieties, such as American sorghum, *Nilva*, and *Sundia* where most of the grains have their glumes on them, the spores lying between the glumes and the seed coats escape as the solution does not reach them. The same is the case with oats too. In such cases formalin should be tried.

[2] Two and a half tolas=An ounce.

direction was made in 1905. A note was drawn up on smut and its treatment. This was issued to all the Collectors and repeatedly communicated to the vernacular papers. In 1909 special district officers known as Divisional Inspectors of Agriculture were appointed, and since then the advice began to reach an increasing number of people every year. The first departmental leaflet was issued in the same year and the steeping process became a feature of all shows and exhibitions. People were shown the efficiency of the treatment on the Government Farms and demonstration plots. A further change took place in 1910 when the writer was appointed Assistant Mycologist to the Department. He soon found that with all the activities of the Department the progress was very slow. The reason of this comparative slow success of the methods previously used to push on the steeping practice among the cultivators, was that the shows and demonstrations and other activities of the Department were chiefly carried on at a time rather remote from the sowing time. It thus happened that the cultivator either forgot all about the demonstrations or his enthusiasm was much diminished and he did not make use of his knowledge. The writer thought, therefore, that the proper way was to approach the cultivator directly at the sowing time and get him to do steeping in some part of his fields. The work was accordingly started by the writer in 1911 at different centres in Satara and Belgaum districts. That year in all 13 villages were visited and seed sufficient for 10,000 acres was treated. A second visit was made at the harvest time, and the decided advantages of the steeping practice, which were very evident in the treated fields, were impressed upon the minds of the cultivators. A report on the work was submitted to the Director of Agriculture proposing to continue this process of approaching the cultivators at sowing time on their own fields. As a result of this report the district staff was instructed to carry on the work, and consequently in the following year 1912 seed for a much larger area than ever before (extending over 150 villages of seven districts, *viz.*, Surat, Broach, Sholapur, Satara, Bijapur, Belgaum, and Dharwar) was treated. A second report was submitted on the results of this work and the necessity of continuing the campaign against this most common but easily preventible malady was urged. The work was taken up very enthusiastically by the district staff, and as a consequence a good many cultivators began to practise it as one of the operations in the cultivation of the crop. This increased work naturally created a large demand for copper sulphate. In order to meet this demand and to distribute copper sulphate and a knowledge of its use into the remotest corners of the Presidency, small packets of copper sulphate were prepared, worth an anna, containing material

sufficient for treating seed for four acres and with instructions for use printed in all the vernaculars of the Presidency. Since this system was introduced the practice of steeping has been rapidly extending among the cultivators. The increase in popularity of this measure can be seen from the following table :—

Year	Number of packets sold	Number of shows and demonstrations	Number of cultivators who visited the demonstration plots
1913-14 . .	4,000	10 111	To the Poona Farm 2,249 people came from the 26 talukas of the Central Division. To the Dharwar Farm 1,000 from the three districts of Bijapur, Belgaum, and Dharwar; 200 came to the Surat Farm.
1914-15 . .	40,000	4 62	800 to the Poona Farm from the four districts of Poona, Satara, Sholapur, and Ahmednagar. Dohad Farm 30, Dhulia Farm 800, Ahmednagar 75, Vadala 100, Dharwar 683.
1915-16 . .	43,455	7 150	850 to the Poona Farm from Satara, Ahmednagar, Nasik, and Sholapur districts. Dohad 100, Dharwar 100, Gokak 300.

It is satisfactory to note that in a good many places Revenue Officers, Agricultural Associations, Co-operative Societies, and many public-spirited men[1] are also helping the Department in selling these packets. Many cultivators are now obtaining copper sulphate from other sources and using it. The propaganda is being carried on very vigorously in the Southern Division. In 1914-15 an extensive campaign was undertaken and steeping was demonstrated in 75 villages of the Sholapur District, 17 of the Satara

[1] It should be noted here that the suggestion with regard to the packets originally came from Mr. Sabnis of Savadatti, Belgaum District, one of the most enthusiastic local workers in the cause of agricultural improvement. The packets are prepared for the Department by Mr. A. B. Modak, Proprietor, The Union Agency, Prag Mahal, Bombay. Mr. Modak has also been greatly instrumental in popularizing these packets.

District, and in 21 talukas of Belgaum, Bijapur and Dharwar districts. In 1915-16 the campaign was undertaken on a still more extensive scale, and as a result there was hardly any important village where the steeping had not been demonstrated. Already some villages (Hulkoti and Kurtkoti) in the Southern Division are now quite free from smut. In the Central Division Mr. Knight, Professor of Agriculture, has made a move on the same line and work has been started in a village near Poona. From the number of packets sold it is evident that the cultivators must have prevented a loss amounting to a million rupees. This is a substantial testimony of the practical and monetary value of the mycological branch of the work of the Department. However, this saving is small when compared to the annual total loss of twenty million rupees. But every effort will be made to push on this propaganda, and it is hoped that in the near future the disease will be for all practical purposes exterminated and the large losses caused to the cultivator minimized.

Prussic Acid in Burma Beans.

[*Received for publication on 19th October, 1917.*]

Introductory.

THIS question was first raised in a letter received by the Director of Agriculture from the Director of the Imperial Institute who pointed out that the poisonous character of occasional cargoes of Burma beans had been noticed by London importing firms.

Analyses of beans from various sources were quoted in this letter and the suggestion made that the Department might encourage the cultivation of varieties freer from hydrogen cyanide than *Phaseolus lunatus*.

This letter was considered at a Departmental Conference in 1912 when the following lines of work were decided upon :—

1. Importation of Madagascar beans to be grown here and tested by the Imperial Institute.
2. Collection of all bean varieties grown in the province for submission of samples to the Imperial Institute.

On his return from leave the Agricultural Chemist proposed to undertake work on the prussic acid content of the commonest Burma bean *Pe-gya*. This was at the time not approved of, but a Conference held a year later raised no objection and accordingly work was commenced.

The work on the Madagascar bean has been carried on in the meantime and progress on it has been regularly reported in the annual report of the Mandalay Agricultural Station.

The conclusions arrived at up to the present are :—

1. The cultures so far examined are not suitable agriculturally to replace *Pe-gya* and *Pe-byu-gale*.
2. Prussic acid determinations showed an increase of poison for two years from 0·0025 to 0·008. Next year, however, the figure dropped to 0·004.

These differences were attributed to variations in climatic conditions. We have, however, no real clue to the manner in which the climate affects the poison content.

In any case, the Madagascar bean has not solved our difficulties. Its hydrogen cyanide content has increased and the plant has been found to be agriculturally unsuitable to replace the beans which it was intended to replace. Analyses of selected red and white beans grown

by the Department were also made by the Imperial Institute. The figures showed great variations. Generally speaking the red beans were the worst and the white beans worse than the Madagascar bean.

The results with the Burma beans were of course expected but the results with the Madagascar bean were particularly discouraging as they seemed to show that our climate and soil conditions tended invariably to maintain the hydrogen cyanide content of *Phaseolus lunatus* beans at a high level.

The present enquiry based on a search for non-poisonous cultures from the ordinary Burmese crop of *Pe-gya*, has yielded more encouraging results.

Analytical Processes.

In commencing this work the following recognized method was first tested :—

The sample to be analysed is ground fine and extracted with alcohol until all the glucoside has been removed.

The alcoholic liquid containing the glucoside is evaporated, taken up with water hydrolized with dilute acid and the hydrogen cyanide distilled off and absorbed into sodium bicarbonate solution.

The hydrogen cyanide in this liquid is determined by iodine titration. The first two modifications found to be necessary were :—

(*a*) *Improved distillation.* This was effected by allowing a slow current of air to bubble through the hydrolized liquid heated in a water bath.

(*b*) *Absorption of hydrogen cyanide.* By distilling hydrogen cyanide solutions of known strength it was found that absorption in sodium bicarbonate solution was generally far from complete. An absorption tower of glass beads was therefore arranged. This gave perfect satisfaction with potassium cyanide solutions of known strength.

The next point noted was that successive distillates from bean extract continued to give a slight iodine reaction for a long time after the prussic acid had been entirely removed.

This has been proved over and over again and must be accepted as quite certain. That it is not due, for instance, to the presence of traces of sulphurous acid when hydrolysis is effected with sulphuric acid is proved by the fact that the identical difficulty is encountered if hydrolysis is effected with hydrochloric acid.

In the case of this bean therefore the iodine titration cannot be relied upon to give a true figure for hydrogen cyanide content. An

attempt was made to improve conditions by altering the strength of acid used for hydrolysis.

This had little or no effect on the reduction of iodine absorbing substances other than hydrogen cyanide but materially reduced the rate of liberation of prussic acid. Nothing was to be gained in this way therefore.

A series of experiments was then undertaken to determine how far the formation of Prussian Blue could be used for the estimation of hydrogen cyanide.

This reaction has been used by a number of workers for this purpose, but none of the methods described was applicable in the present case. The action had, for reasons which need not be entered into, to take place in about 400 c.c. liquid containing sodium hydrogen carbonate and had preferably to take place without the aid of heat.

Starting with these conditions a large number of tests were made. Of these only the following need be quoted here :—

1. Effect of quantity of ferrous sulphate used on yield of Prussian Blue. The following experiment was made with 2 c.c. and 5 c.c. potassium cyanide solutions always made up to 400 c.c.

In each case all other factors remaining the same the amount of ferrous sulphate was varied. The Prussian Blue formed was filtered, ignited and weighed as (Fe_2O_3) ferric oxide.

10 per cent. $FeSO_4$ (ferrous sulphate)	Ferric oxide (Fe_2O_3) OBTAINED	
	using 2 c.c. KCN (Potassium cyanide)	using 5 c.c. KCN (Potassium cyanide)
4 c.c.	0·0014	0·0036
8 c.c.	0·0018	0·0050
16 c.c.	0·0022	0·0054
24 c.c.	0·0022	0·0054

These figures show that quantities up to 8 c.c. of ferrous sulphate solution were not sufficient to obtain maximum yield of Prussian Blue.

For all subsequent determinations 16 c.c. of ferrous sulphate solution were used. It need scarcely be remarked that this test had to be repeated numbers of times with other conditions also varied before optimum results were obtained.

2. Effect of alkali on yield of Prussian Blue. It was noticed that in certain cases, the presence of sodium hydrogen carbonate may entirely prevent the formation of Prussian Blue.

Various proportions of alkali hydrate were added to the liquid and were found to have an important effect on the yield of Prussian Blue. The point is of interest and deserves attention.

The following set of results will indicate the effect of the nature of the alkali upon the result. The experiment was made with three strengths of potassium cyanide, in every case using 16 c.c. of ferrous sulphate solution, shaking for 3 hours and acidifying. The Prussian Blue was determined after reprecipitation, filtration and ignition as (Fe_2O_3) ferric oxide.

Alkali used		Ferric oxide (Fe_2O_3) obtained		
Normal Pot. Hydroxide	Normal Bicarbonate	using 5 c.c. KCN (Potassium cyanide)	using 2 c.c. KCN (Potassium cyanide)	using 0·5 c.c. KCN (Potassium cyanide)
0 . .	60	0·0044	0·0014	0·0002
10 . .	50	0·0042	0·0016	0·0004
20 . .	40	0·0050	0·0020	0·0004
30 . .	30	0·0052	0·0020	0·0004
40 . .	20	0·0044	0·0010	0·0000
50 . .	10	0·0042	0·0008	0·0000
60 . .	0	0·0038	0·0006	0·0000

These figures show clearly that to obtain maximum yields, it is essential to adjust the proportion of alkali and carbonate to be approximately equal to normal carbonate.

In fact, when dealing with small quantities of hydrogen cyanide, a weighable quantity of Prussian Blue cannot be obtained unless this adjustment is made.

In the case of 0·5 c.c. potassium cyanide in the table above, for example, where zero weights are given, there was actually no colour visible whilst using 10, 20 and 30 c.c. of potassium hydroxide an intensely coloured precipitate of Prussian Blue was obtained. It should be stated here that the filter paper invariably absorbs a certain amount of the soluble salts. In a very large number of blank determinations the ash was found to weigh 0·0004 gm. with perfect constancy. This correction has been made in all the above and in subsequent weighings.

There is little doubt that the effect of the nature of the alkali used is due in part to the nature of the ferrous oxide precipitate formed.

When potassium hydroxide is in excess, the green voluminous hydroxide originally precipitated very soon turns black, shrinks and forms a relatively granular precipitate.

With the normal carbonate a dark blue-green voluminous precipitate is formed which remains unaltered and obviously offers a large reaction surface to the hydrogen cyanide in solution.

3. The process adopted for determination of hydrogen cyanide. As a result of a number of experiments of which two series have been cited, the following process was adopted.

The liquid containing hydrogen cyanide + 30 c.c. sodium hydrogen carbonate made up to between 400 and 500 c.c. in volume is treated with 30 c.c. of normal potassium hydroxide, 16 c.c. ferrous sulphate solution are added and the flask shaken at regular intervals for three hours.

The liquid is then acidified and allowed to stand some days for the Prussian Blue to settle out. The precipitate is then filtered, taken up with a small amount of alkali and the Prussian Blue reprecipitated in a small volume of liquid.

If the amount of Prussian Blue is small, it is determined by colour comparison with standards, if large it is filtered, ignited and weighed as Fe_2O_3 (Ferric oxide).

The Prussian Blue determinations described in the two previous series of experiments were made in this way with the modifications specified in each particular case.

By the method just described, the following results were obtained with different quantities of potassiam cyanide, the liquid in each case being diluted to 500 c.c.

Potassium cyanide	Ferric oxide obtained	
	(1)	(2)
0·2	0·0000	0·0000
0·5	0·0004	0·0004
1·0	0·0010	0·0010
2·0	0·0020	0·0022
5·0	0·0052	0·0054
10·0	0·0108	0·0108

The determinations were made in duplicate. The first set was exactly as described. In the second set the crude ferrocyanide was treated with ammonium chloride which is unnecessary in this case but with bean extracts helps to eliminate organic matter. The strength of the potassium cyanide solution used in this test (as determined both by standard iodine and standard silver nitrate) was 0·000938 gm. hydrogen cyanide per c.c.

Ten c.c. of this liquid completely converted to Prussian Blue and ignited should yield theoretically 0·0108 gm. ferric oxide, *i.e.*, the identical figure obtained above.

The precipitation in this case therefore appears to be absolutely quantitative. It may be noticed however that with very dilute solutions undoubted loss occurs.

This may be due either to incomplete reaction or to incomplete precipitation. The limit of quantitative precipitation is reached with 1 c.c. of potassium cyanide solution. Below this amount and down to 0·2 c.c., colorations can be obtained.

The lowest quantity of hydrogen cyanide which has been detected is that contained in 0·2 c.c., *i.e.*, 0·000047 gm. in 500 c.c. liquid or roughly 0·0000001 gm. hydrogen cyanide per c.c.

This is a very favourable result compared with the figures obtained by Anderson (*Journal of the Society of Chemical Industry*, 1916, page 1083).

In our case however relatively very large volumes of liquid were employed and the colours then concentrated by reprecipitation. There is no doubt, however, that the favourable results are mainly due to the discovery that the action is more perfect when the alkalinity of the liquid is carefully adjusted.

The process as worked out and described here should obviously be most effective in determining the small quantities of hydrogen cyanide present in beans. It was remarked earlier that alcoholic extracts of *Pe-gya* when hydrolized by dilute acids continued to evolve substances which reacted with iodine after all the hydrogen cyanide had been distilled off. This was very easily proved by the above Prussian Blue method.

A third fraction distilled from a bean extract was divided into three parts. One part was titrated and gave an appreciable iodine absorption figure. The second part was treated for Prussian Blue reaction and gave no trace of colour. To the third part 0·2 c.c. potassium cyanide was added. This liquid on treatment gave the Prussian Blue reaction.

The tests show that the original liquid though it gave an iodine reaction contained no measurable amount of hydrogen cyanide.

Prussic acid in Pe-gya cultures.

About 100 single plant samples were collected from cultivators' fields from the typical *Pe-gya* growing areas in Sagaing District.

These were all grown separately and analysis of the crops commenced ; the process employed being the Prussian Blue method already described.

When the next sowing season arrived, all the cultures had not been tested and it was decided therefore to confine the enquiry in the first place to those cultures which had been examined. The prussic acid content of these ranged from 0·0004 per cent. to 0·03 per cent.

From these cultures the two best, the two worst and four intermediate specimens were selected for further work. From their appearance absolutely no distinction was possible between the samples. They all consisted of a mixture of distinctly mottled with some more uniformly brown-coloured beans.

This brown colour is known to develop gradually on keeping. All the beans become darker in time, but with some the colour change is more rapid than with others.

It seemed desirable to find out whether this colour difference to be found within each single plant culture was in any way connected with the prussic acid content.

To test this point, the two best and the two worst cultures were each divided into two sub-samples consisting of—

(*a*) distinctly mottled seed ;

(*b*) more uniformly brown-coloured seed.

There could be no doubt that if prussic acid content were connected with the observed colour differences, this separation though obviously far from perfect would give positive results in the succeeding crop.

The following table shows the prussic acid content of the cultures used :—

Sample		Hydrogen cyanide content
1. Mottled seed	1 and 2 mixed	0·0004
2. Brown seed		
3. Mottled seed	3 and 4 mixed	0·0012
4. Brown seed		
5. Mixed	....	0·0018
6. Mixed	....	0·0022
7. Mixed	....	0·0030
8. Mixed	....	0·0112
9. Mottled seed	9 and 10 mixed	0·0138
10. Brown seed		
11. Mottled seed	11 and 12 mixed	0·0347
12. Brown seed		

NOTE. Nos. 1 and 2 were mottled and brown seed obtained from a single plant culture which gave average hydrogen cyanide content 0·0004. The same remark applied to Nos. 3 and 4, Nos. 9 and 10, and Nos. 11 and 12.

These seeds were grown at three different stations during the past season. The places selected were—

(1) Mandalay—in the dry zone.

(2) Hmawbi—in the wet delta zone.

(3) Tatkon—in middle Burma where the rainfall is intermediate in character.

At each station the cultures were grown in parallel rows of 20 plants, the whole series being duplicated.

The sowing season was in each case unfavourable and germination poor especially at Hmawbi.

Some cultures from which only a few plants grew up were not examined. For Hmawbi and Tatkon the crops from the two identically numbered rows were combined to yield one sample and analysed mixed.

At Mandalay, the crop from each row was analysed separately and thus duplicate figures obtained to verify the results.

Further at Mandalay sowings were made at three different dates. From these the effect of sowing season upon hydrogen cyanide content can be estimated.

The following results were obtained :—

Hydrogen cyanide in *Pe-gya* crops from selected cultures.

	Mandalay			Hmawbi	Tatkon
	1st sowing	2nd sowing	3rd sowing		
1 . . .	..	..	0·0008	..	0·0010
2 . . .	0·0008	0·0012	0·0010	0·0015	0·0015
3 . . .	..	0·0016	0·0015	..	0·0016
4 . . .	0·0016	0.0021	..	0·0017	0.0016
5 . . .	0·0016	0·0021	0·0021	..	0·0021
6 . . .	0·0021	0·0027	0·0026	0·0027	0·0024
7 . . .	0·0028	0·0043	0·0062	0·0036	0·0036
8 . . .	0·0058	0·0072	0·0146	0·0094	0·0043
9 . . .	..	0·0249	..	..	0·0108
10 . . .	0·0083	0·0242	..	0·0220	0·0101
11 . . .	..	0·0317	0·0317	..	0·0180
12 . . .	0·0250	0·0314	0·0325	0·0311	0·0188

In spite of some unavoidable blanks, the table of results is sufficiently complete to show conclusively that whatever soil, climate or season these cultures were grown in, a steady increase of hydrogen cyanide was obtained on passing down the series.

This is to say the seed which contained least hydrogen cyanide last year again contains the least when grown under a variety of conditions.

Similarly the seed with most hydrogen cyanide last year is found to contain most this year.

In other words the cultures have maintained the property of producing the same relative amounts of poison. As this has been shown to be the case under almost the greatest extremes of environment obtainable in the Province, there can be no doubt left that the content of hydrogen cyanide is a characteristic property of each one of cultures which has been separated out. As long as mixing is prevented the cultures must maintain these differences.

We therefore are in possession of cultures which contain quite harmless amounts of hydrogen cyanide and we know they will breed true in this respect.

It remains still to consider how far the effects of soil and climate may counteract this satisfactory conclusion. That the climate can very considerably modify the amount of hydrogen cyanide is seen from the results of the three sowings at Mandalay. The general superiority of the early crop is in this case very marked. It is of course impossible at present to say that the early crop will always be superior in this respect to the later sowings. This point is now being studied. It is certain however that marked differences are to be expected.

That the combined effects of soil and climate can also cause considerable variations in hydrogen cyanide content of the crop is seen by comparing the Hmawbi and Tatkon results. The Hmawbi figures were for this particular year much higher than those of Tatkon. The effect of the soil is probably considerable and is being studied more fully.

The points so far considered certainly prove without doubt that from a cultivator's ordinary mixed crop of seed, great variations in the content of hydrogen cyanide are to be expected under different conditions of growth. An examination of the table above, however, shows that this is not necessarily the case with our best selected cultures.

It will be noticed that Nos. 1 and 2 give practically the same values under all the conditions tested. The figures in this case require to be more fully investigated by working on a larger scale to bring out small differences that we must expect from variation of environment. The

results obtained so far however show that the hydrogen cyanide in these cultures (whether it does or does not appreciably vary with varying environment) remains very low under each of the extı .onditions tested.

Exceptionally unfavourable conditions may of course exist and therefore the main bean-producing areas should be tested by the above methods.

It was explained earlier that the pairs of samples 1 and 2, 3 and 4, 9 and 10 ; 11 and 12 were really four main and distinct cultures each of which had been divided into two parts according to slight colour variation in the seeds.

The results for these samples are brought together here :—

	1	2	3	4	9	10	11	12
Mandalay	0·0008	0·0010	0·0016	0·0021	0·0249	0·0242	0·0317	0·0314
Tatkon	0·0010	0·0015	0·0016	0·0016	0·0108	0·0101	0·0180	0·0188

These figures show the effect of environment already referred to. For example Nos. 9 and 10 grown at Mandalay give much higher figures than when grown at Tatkon.

The point to note however is that Nos. 9 and 10 grown at Mandalay give practically identical figures. Under Tatkon conditions, the hydrogen cyanide content of these two samples is notably altered but the alteration is the same for both samples. These remarks apply equally well to the samples 11 and 12 derived from another main culture.

These results prove that the colour differences observed within each of our main cultures do not indicate differences in hydrogen cyanide production by the progeny of these seeds. In other words cultures which are pure as regards the production of hydrogen cyanide may contain seeds which differ from one another slightly in colour.

CONCLUSIONS.

The results obtained in this work may be summarized as follows :—

1. The content of hydrogen cyanide is an inherited character of pure single plant cultures. These cultures may be multiplied and will maintain the differences noted.

2. The hydrogen cyanide present in the cultures is found to vary considerably according to soil and climatic conditions.
3. Cultures giving low amounts of hydrogen cyanide in one locality give low figures under all the conditions tested.
4. Differences in colour in seeds from a single culture do not indicate differences in the power of producing hydrogen cyanide in their progeny.
5. The best cultures so far found always contain some hydrogen cyanide. But the quantity is only half that contained in the original sample of Madagascar bean imported into the Province as safe.